ANALYSIS OF ALTERNATIVES

and

SOCIO-ECONOMIC ANALYSIS

Legal name of applicant(s):	LUC (UK) Limited
Submitted by:	LUC (UK) Limited
Date:	24.06.2022
Substance:	2,2'-Dichloro-4,4'-methylenedianiline (MOCA, MbOCA) [CAS 101-14-4; EC 202-918-9]
Use title:	Industrial use of 2,2'-Dichloro-4,4'-methylenedianiline (MOCA) in the manufacture of high-performance polyurethanes specifically for heavy-duty rollers, tensioner pads and spring blocks with high reliability requirements for offshore energy and renewables sectors
Use number:	Use #2

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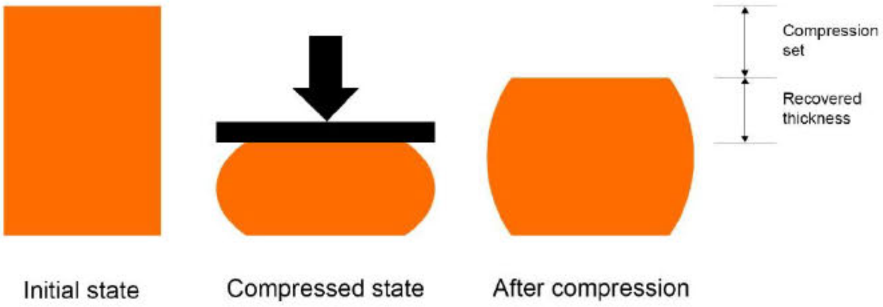
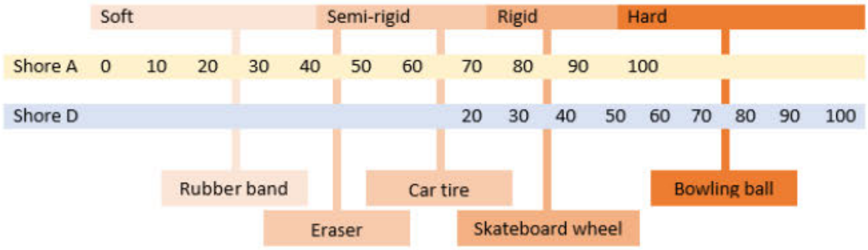
LIST OF ABBREVIATIONS

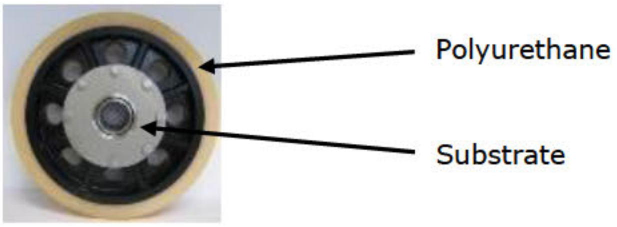
3L-PP	3-layer polypropylene
AISI	American Iron and Steel Institute
AoA	Analysis of Alternatives
BAU	Business as Usual
BDO	Butane-1,4-diol
C&L	Classification and Labelling
CAS	Chemical Abstract Service
CLP	Classification, Labelling and Packaging
CoF	Coefficient of Friction
CSR	Chemical Safety Report
#A	#A
EC	European Commission
ECHA	European Chemicals Agency
ELR	Excessive Lifetime Risk
EU	European Union
HH	Human Health
HQEE	2,2'-p-phenylenedioxydiethanol
ID	Identity
ISO	International Organization for Standardization
IUPAC	International Union of Pure and Applied Chemistry
LEV	Local Exhaust Ventilation
LF-MDI	Low-Free MDI
MbOCA	MOCA
#A	#A
MOCA	2,2'-Dichloro-4,4'-methylenedianiline
NDI	1,5-naphthalene diisocyanate
OEL	Occupational Exposure Limits
OELV	Occupational Exposure Limit Value
OSHA	Occupational Safety and Health Administration
PBT	Persistent, Bioaccumulative and Toxic
PPDI	1,4-Phenylene diisocyanate
PU	Polyurethane
R&D	Research and Development
RAC	Risk Assessment Committee
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals
SEA	Socio-economic Analysis
SEAC	Committee for Socio-economic Analysis
SME	Small and medium-sized enterprise
STOT-RE	Specific target organ toxicity - repeat exposure
STOT-SE	Specific target organ toxicity - single exposure
SVHC	Substance with Very High Concern
TDI	Toluene diisocyanate
TWA	Time Weighted Average
UK	The United Kingdom

Glossary

Term	**Definition**
Abrasion resistance (unit: mm^3) Standard: ISO 4649 method B	Abrasion occurs when one object moves over another, resulting in minute tears in the objects' surface. The minute tears are caused from minute sections of the object's surface breaking off. Abrasion resistance is therefore measured as the volume loss due to abrasion. A polyurethane has a high abrasion resistance when the volume loss is low while it has a low abrasion resistance if the volume loss is high.
Adhesion	The bonding of the polyurethane layer to a **substrate.** A weak adhesion will lead to the separation of the polyurethane layer and the substrate requiring the part to changed.
Casting	The action of filling moulds by pouring a liquid polyurethane (PU) mixture into them.
Catalyst	A substance which increases the speed of a chemical reaction, which is not consumed in the catalytic reaction.
Coefficient of Friction (unit: dimensionless) Standard: internal	Friction is the resistance to motion that one object encounters when moving over another. Friction enables traction. For instance, cars rely on friction between the wheels and asphalt to move forward and brake. The Coefficient of Friction (CoF) represents the ratio between the force of friction between a pair of objects (i.e. the force that opposes the motion of an object) and the force pressing them together (also known as normal force). The CoF varies based on the two objects/surfaces that are causing friction. It is therefore a system property and does not only depend on the properties of the PU. The CoF typically has a value comprised between 0 and 1 but it can also be greater than 1 in some cases. If the CoF is 0, it means there is no friction between the two objects in question, which is a situation not typically encountered in everyday life. When the CoF is 1, the force of friction is equal to the force pressing the two objects together (normal force). Ice on steel will have a low CoF while it will be high for rubber on rubber. A high CoF is desirable for applications where it is required that no slippage occurs between the two objects (i.e. grip is needed). For instance, friction is needed between the drive roller and the conveyor belt in order for the conveyor belt to move forward. In contrast, a low CoF is desirable for applications where sliding is needed.

Term	**Definition**
Compression set (unit: %) Standard: ISO 815-1	When a material is compressed, its shape may be permanently altered. The permanent deformation that remains in the material after being compressed is called compression set (see figure below).  A compression set of 0 % means that the material has fully recovered its original thickness. In contrast, a compression set of 100 % means that there was no recovery.
Curing	A chemical process where cross-links between polymer chains are formed which results in the toughening of the material.
Cutting resistance	Cutting is a type of abrasive wear (see **abrasion resistance**) that involves sharp objects or blades penetrating the material surface. A polyurethane with high cutting resistance can withstand the cutting action of such objects. High cutting resistance is a combination of high tear resistance, low abrasion and high toughness.
Damping	A PU with high damping prevents or reduces vibrations induced to it by converting energy to heat. Related to **rebound resilience**.
Deflection (unit: %)	Deflection is the degree to which a polyurethane is displaced when compressed.
Diisocyanate	A substance containing two isocyanate functional groups (R-N=C=O). It is one of the two components, which form the prepolymer.
Dynamic load bearing	Dynamic load bearing represents the PU's ability to withstand a load that is non-static (i.e. in movement) without the presence of structural damage or cracks in the object or flaking of the surface.
Dynamic properties	Refers to the dynamic properties exhibited by the end-product when subjected to repeated cyclic deformations and flexing.
Elongation at break (unit: %) Standard: ISO 37	Elongation at break indicates how much a material can be stretched before it breaks (i.e. ductility). A material with high elongation at break percentage will stretch and deform more before breaking than a material with low elongation at break percentage.

Term	**Definition**
Fatigue	Fatigue is one of the most common sources of failure of polyurethane parts. It is the deterioration the PU undergoes due to cycling loading (i.e. repeated application and removal of a load on the PU part, which is typical during PU product end-use) . Fatigue damage can occur even when the stress experienced by the part is far below the limit it can withstand. Fatigue develops in three stage process: 1. After multiple load cycles, localised structural damage at the microscopic level may occur. The damage develops until a macroscopic crack is formed. 2. The crack grows with each load cycle until it reaches a critical size. 3. At this point, the crack rapidly propagates in the material leading to the complete fracture of the part.
Hardness (unit: °A or °D) Standard: ISO 48-4	In the polyurethane industry, hardness corresponds to the polyurethanes resistance to localized deformation (i.e. indentation). Cast polyurethanes are typically measured using the Shore A (°A) and Shore D (°D) hardness scales (see figure below). The higher the number, the harder the polyurethane. 
Hysteresis	Rebound resilience gives an indication of the polyurethane's hysteresis. Hysteresis is the energy that is lost as heat during recovery due to internal friction. Hysteresis will therefore cause the polyurethane to build up heat.
Mechanical strength	Mechanical strength corresponds to the materials ability to resist an applied load without plastic deformation (i.e. irreversible deformation) or failure. Important material properties that influence mechanical strength include hardness and tensile strength.
Mould	A metal recipient, which has the shape of the desired end-product. There is an example of a mould for a wheel on the right. 
Moulder	A polyurethane manufacturer who uses raw materials (i.e. a prepolymer and MOCA pellets) to produce different PU-parts for many end-use sectors.
Oven	A hot-air chamber that has precise temperature controls.

Term	**Definition**
Polyol	A substance containing multiple hydroxyl groups (-OH). It is one of the two components, which form the prepolymer.
Post-cure	After a polyurethane part has been cured, it is removed from the mould and placed back in the oven for post-cure. Phase separation of hard and soft segments occurs during post-curing. This step is required to achieve high mechanical and dynamic properties.
Pot life (unit: minutes)	The timeframe between adding chain extender to prepolymer and polyurethane mixture being too viscous to cast.
Primer	A substance designed to chemically react with the **substrate** and polyurethane such that a strong bond is formed between them.
Rebound resilience (unit: %) Standard: ISO 4662	Energy is required to deform a material. When a material recovers from deformation, part of this energy is returned. Rebound resilience is the ratio of energy returned to the energy applied, expressed as a percentage. A material with 100 % rebound resilience returns all the energy applied. A bouncy ball is an example of an object with high rebound resilience. A material with low rebound resilience will return less energy during recovery. This type of material is good for applications where bounce-back has to be minimized. A material with inappropriately low rebound resilience may melt during use.
Scrap rate	Percentage of PU products rejected during production due to faults (e.g. cracks, flaky surface) and are therefore, discarded because they cannot be sold.
Strain (unit: %)	The deformation of the PU material due to a force (i.e. tension) applied to it.
Stress (unit: MPa)	The amount of load (force per area) exerted on the PU material.
Substrate	Material on which the polyurethane is casted. Typically made of metal. Not all polyurethanes are casted on a substrate. 

Term	**Definition**
Tear resistance (unit: kN/m) Standard: ISO 34-1 method B, procedure b	Tear resistance (also called tear strength) corresponds to the polyurethane's ability to resist the formation and propagation of tears and nicks.
Tensile strength (unit: Pa) Standard: ISO 37	Tensile strength (also called ultimate tensile strength) is one of the most important property in material science. It represents the capacity of a material such as polyurethane to withstand being stretched or pulled apart (i.e. tension) without breaking. A material with high tensile strength will withstand a lot of tension before breaking (e.g. steel) while a material with low tensile strength will break more easily (e.g. rubber). Measuring tensile strength thus helps predicting how the finished product will behave in use.
Toughness	Toughness corresponds to the polyurethane's ability to absorb energy and deform plastically before breaking. It can be seen as the polyurethane's resistance to fracture when under load. The toughness of PU is measured by calculating the area under the stress-strain curve.
Viscosity (unit: mPa*s)	Viscosity can be thought as a liquid's "thickness". A substance with low viscosity (e.g. water) will flow more quickly when poured than a substance with high viscosity (e.g. honey).

DECLARATION

The Applicant, LUC (UK) Limited, is aware of the fact that further evidence might be requested by the UK HSE to support the information provided in this document.

Also, we request that the information blanked out in the "public version" of the Analysis of Alternatives and Socio-economic Analysis is not disclosed. We hereby declare that, to the best of our knowledge as of today (24.06.2022), the information is not publicly available, and, in accordance with the due measures of protection that we have implemented, a member of the public should not be able to obtain access to this information without our consent or that of the third party whose commercial interests are at stake.

Signature:

Date, Place: 24th June 2022
Cardiff.

1. SUMMARY

The Analysis of Alternatives (AoA) and the Socio-economic Analysis (SEA) form part of the Application for Authorisation (AfA) for the usage of MOCA in the manufacture of high-performance polyurethanes, specifically heavy-duty rollers, tensioner pads and spring blocks with high reliability requirements for the offshore energy and renewables sectors at LUC Group's UK site in Dowlais.

LUC Group is a downstream user of MOCA in the supply chain of Suzhou Xiangyuan New Materials Co., Ltd. (Suzhou) and their use of MOCA is currently covered by the application submitted by REACHLaw acting as only representative for Suzhou under Brexit transitional arrangements, as the Commission has not yet taken a decision on the application. LUC Group submitted a downstream user application to cover its use at 4 sites in the EEA on 20.05.2020 and the ECHA opinion on this application was issued to the Commission for decision making on 28.07.2021. Details of the application are available on the ECHA website.[1] As this application was submitted before the end of the Brexit transition period, it included also use at the UK site. Since the 01.01.2021, the UK site is now under UK REACH and the application submitted under EU REACH is not relevant. LUC (UK) Limited (LUC UK) is submitting this application to cover use at the UK site.

LUC UK manufactures their heavy-duty rollers, tensioner pads and spring blocks in close collaboration with the customers, based on their specifications and the specific end-use. All three product types are manufactured using a low-pressure casting process. The heavy-duty rollers consist of a metal core on which LUC UK casts a layer of polyurethane (PU). Tensioner pads consist of a metal plate on which a polyurethane layer is casted. Spring blocks are fully made of polyurethane and could i.e. bear a hole in their centre. A schematic representation of the products is presented below. Their shape and size will differ based on the specific end-use.

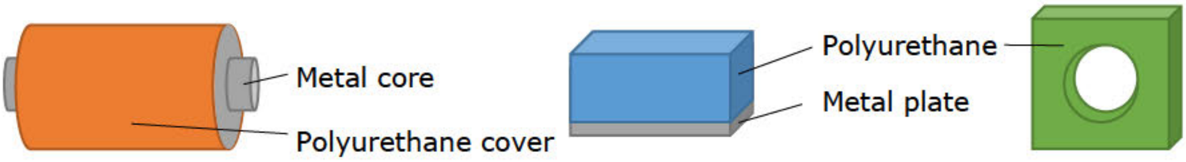


Figure 1. Schematic representation of the products covered by this use. From left to right: heavy-duty roller, tensioner pad and spring block

LUC UK's customers, the end-users, use LUC UK's rollers, pads and blocks on ships dedicated to offshore pipe/cable laying and to offshore installation of windmills (more precisely the part called monopile, which is the foundation of the windmill). These high-end applications require high-performance PU products due to the strict safety measures in place on board of the ships as well as the highly demanding characteristics of the end-use.

Monopiles are extremely big and heavy parts. They can be up to 100 meters long, have a diameter of up to 11 meters and weigh approximately 1500 tonnes. Their installation at

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[1] LUC Group's application for authorisation for 2 uses of MOCA under EU REACH; use 1 ECHA ID 0225-01 and Use 2 ECHA ID 0225-02 available on the ECHA website at https://echa.europa.eu/applications-for-authorisation-previous-consultations

sea on board of a ship is therefore extremely complex and a feat of engineering requiring top-quality PU products.

Offshore pipe-laying is characterised by the installation of oil or gas pipes on the seabed, up to approx. 2000 meters under sea level, using a specific pipe-laying vessel. Due to the complexity of the task, only high-performance PU product can be used.

For these sectors of end-use, the polyurethane is required to have excellent mechanical, friction and dynamic properties. Key properties include:

- **Mechanical strength:** A high mechanical strength is necessary to handle the extreme loads applied on the polyurethane.
- **Dynamic load bearing capacity:** The PU products must be able to withstand the extreme dynamic loads encountered in these industry sectors.
- **Deflective/compression behaviour:** Due to the complexity of pipe laying and monopile installation, the PU products need to have a very specific and accurate compressive/deflective behaviour, which does not change with time.
- **Coefficient of friction:** A high coefficient of friction is important for tensioner pads in order to maintain grip during end-use.
- **Adhesion:** High bonding strengths are necessary to maintain adhesion between the PU and substrates. If delamination occurs, this could lead to major costs, equipment damage and even fatalities.

In addition, LUC UK’s heavy-duty roller, tensioner pads and spring blocks have high durability, high reliability and excellent fatigue properties due to several factors:

The remoteness of the location where the part is used. The ships work dozens or hundreds of kilometres from the shore. Downtime due to PU product failure or resulting accidents forces the ships to interrupt their ongoing operations and return to port, which costs energy, causes delays in the project and causes financial loss.

The dangers associated with a PU product failure are high. The failures could cause tremendous damage to the ship and lead to injury or loss of life. The poor accessibility of the location is a compounding factor for rescue operations. In addition, it is impossible to retrieve a pipe/cable/monopile that is lost at sea.

As safety plays an important role in these industry sectors and the end-use are highly complex, LUC UK needs to provide their clients with high-performance polyurethane products. Such high-performance polyurethanes are achieved when using MOCA as a chain extender/curing agent.

MOCA – a core ingredient in the manufacture of high-performance polyurethane

MOCA has a long and successful history as a flexible chain extender that leads to excellent PU material properties. MOCA-cured polyurethanes are recognised, both by moulders and end-users, as high-quality, high reliability and high-performance products. MOCA key advantages include:

- **Long pot-life:** it allows the casting of large volumes (e.g. the heavy-duty rollers covered by this use). Long pot-life results in less rejected products during manufacture (low scrap rate). See end of Chapter 3.1.1. in the AoA-SEA report of Use 1 of this application for additional information on pot-life.

- **Robust and easy processing:** The properties and the quality of the resulting elastomer are not significantly affected by slight variations in raw material ratios. MOCA also has an excellent solubility in a variety of prepolymers. Both contribute to a low scrap rate.
- **Technical performance:** Tough and durable polyurethanes having excellent mechanical and dynamic properties can easily be produced with MOCA.
- **Economical:** MOCA allows the production of high-performance polyurethane products with excellent price/quality-ratio.
- **High sustainability:** MOCA-cured polyurethane is currently unequalled in terms of sustainability. It is easy to process and has a long pot-life, which results in low scrap rates. In addition, the processing temperatures to manufacture MOCA PU are relatively low and the curing times are short (i.e. less time required in the curing ovens). This limits the energy consumption of the production process. Furthermore, MOCA-cured PU products are known to have high durability, reliability and fatigue properties thus, they need to be changed or recovered less often. As cast polyurethane cannot be recycled, it is critical to limit the amount of wastes generated and maximising the lifetime of products.

  Overall, MOCA PU has a lower load on the environment than alternatives currently available on the market due to being associated with low amounts of waste and lower energy consumptions.
- **Proven track-record:** MOCA-cured polyurethane products benefit from a strong customer confidence, which results from decades of their successful use.

Potential alternatives to MOCA

LUC Group has looked for and tested potential alternatives to MOCA since June 2009. In this AoA, the most common alternatives to MOCA according to raw material manufacturers or the ones that gave the best results are discussed. However, none of the alternative were found to be suitable to replace MOCA in the manufacture of high-performance polyurethane rollers for the offshore energy and renewables sectors. An overview of the results of the alternative assessment is presented in Table 1.

Table 1. Overview of the alternatives assessment results

	TDI/ Addolink® 1604	TDI/ Blend 1	TDI/ Blend 2	NDI/ BDO	PPDI/ BDO	PPDI/ HQEE
Technical feasibility	🟥	🟥	🟥	🟥	🟥	🟥
Economic feasibility	🟥	🟥	🟥	🟥	🟥	🟥
Availability	🟥	🟨🟥	🟨🟥	🟥	🟩	🟩
Safety considerations	🟩	🟩	🟩	🟩	🟩	🟩

Red = requirement not met, yellow = fulfilment of the criteria not clear, green = requirement met

The alternative cured polyurethanes were found to have significant limitations in terms of technical performance, including insufficient mechanical strength, especially in terms of tensile strength, but also insufficient dynamic load bearing capacity, deflective/ compression behaviour, coefficient of friction, fatigue properties and reliability. In some cases, the pot-life was so short, it was not even possible to cast the products at all. These materials are therefore unsuitable for use in the high-performance polyurethane PU products for the offshore energy and renewables sectors.

In addition to technical limitations, the alternative PU materials had higher environmental loads. The alternatives had one or more of the following limitations in terms of sustainability:

- Lower fatigue properties
    - This results in products having shorter durability thus, the PU parts need to be changed or recovered more often. This increases the amount of wastes generated.
- Shorter pot-lives
    - Some PU systems have shorter pot-life, which increases the risk for delamination (i.e. separation of the PU layer from the substrate). This shortens the product's lifetime.
- Longer curing times and higher energy consumption
    - Longer curing times means that more oven space will be needed to equal the output achieved with MOCA PU and for a longer time. This also translates into higher energy consumption and production costs (especially considering the current energy price levels in Europe) as curing is carried out at elevated temperatures.
    - Some chain extenders need higher processing temperatures as they have higher melting points compared to MOCA and/or they crystallise at lower temperatures. This results into higher energy consumption.
- Higher scrap rate
    - Some PU systems have shorter pot-life and/or they are complex to process. Both increases the number of defects in PU, which leads to a higher rejection of products (higher scrap rate).

End users have no motivations to change to non-MOCA based PU products

LUC UK's customers (the end-users) are accustomed to TDI/MOCA-PU products. Changing to non-MOCA based PU products would require end-users to switch to relatively untested products for installations that have long service life and where any downtime for repair, maintenance or replacement will result in lost production time. Furthermore, the current non-MOCA based products are more expensive to produce while their performance may be lower at best, at worst, the non-MOCA based products do not work at all. As LUC UK's customers have no driver to transfer to non-MOCA based products, there is a very real risk that customers prefer to stick with what they know and stay with TDI/MOCA-PU products. If LUC UK's customers were in the same situation where they would also need to find alternatives, the situation would be easier in that the goal would be a common one. However, the current situation is that LUC UK's customers are only concerned about price and performance.

TDI/MOCA-PU products from outside of the UK distorts the market

LUC UK's customers can easily switch to non-UK moulders. As the finished PU products do not contain any MOCA, they are not affected by authorisation thus, non-UK moulders can continue freely to place their MOCA-cured PU products on the UK market. LUC UK has to compete with these non-UK moulders, which puts them in a vulnerable position in that at any time, LUC UK's customers may leave them for a non-UK moulder. Therefore, any non-MOCA based products LUC UK manufacture must perform at least as well as their TDI/MOCA-counterparts. This also means that it is essentially impossible for LUC UK to reflect the substitution costs (estimated at 850-962 k GBP) or the higher production costs in the price of the non-MOCA based products.

Note that, in the non-use scenario LUC Group would close LUC UK's production and business. LUC Group would relocate LUC UK's entire production to its facilities in the EU.

Review period

LUC Group has made extensive efforts to find a suitable replacement and substitute for MOCA in the manufacture of their PU products. LUC Group tested several dozens of non-MOCA based curatives and polyurethane systems, including like-for-like diamine alternatives, chain extender blends and non-TDI polyurethane systems.

LUC Group has an extensive knowledge of polyurethane chemistry. They have been using both MOCA-based and non-MOCA based PU systems for several decades (e.g. NDI systems since 1973 and PPDI systems since 1987). Thus, the characteristics, advantages and drawbacks of the PU systems currently available on the market are well-known to LUC Group. LUC Group has substituted MOCA wherever it was possible (e.g. PU products with lower technical requirements or where pot-life of the material was not problematic). However, for the high-performance PU products, such as the PU products for the offshore energy and renewables sectors, the alternatives were found to lack the required pot-lives, mechanical and dynamic properties. Therefore, the present authorisation application covers the products for which no suitable alternatives were found.

LUC UK took several factors into account when deriving the review period requested in this application. These are the following:

- LUC Group has tested several dozens of alternatives to MOCA since 2009 however, none of the alternatives have been suitable to replace MOCA in the production of high-performance polyurethanes for heavy-duty rollers, tensioner pads and spring blocks covered by Use 2.
- It is currently uncertain when a non-MOCA chain extender that can produce a high-performance and high durability polyurethane material that fulfils every key technical requirements would be available on the market.
- LUC UK is fully dependent on alternative providers to develop new chain extenders/PU systems, thus it can easily take several years before a suitable alternative is available.
- Even if an alternative was to become available, the successful substitution of MOCA with another chain extender or polyurethane system will take many years. It is a time-consuming process requiring extensive testing as well as verification trials at end-user facilities.
- The established reputation of MOCA-cured polyurethanes as high-quality material, alongside the continued availability of MOCA-cured PU products originating from outside the UK make the task of finding a substitute to MOCA more complicated. In order to remain competitive, LUC UK would either need to provide an alternative

PU product performing as well as their MOCA counterparts for the same price or a better performing product for a higher price.

- The most likely non-use scenario is to close the business in the UK and relocate the MOCA-cured manufacture in LUC Group's facilities in the EU (where their use is authorised).
- The monetised benefits of the continued use of MOCA for Use 2 are 0.09 M GBP per year.
- The monetised risks of the continued use of MOCA for Use 2 are 0.000005 M GBP per year.
- The benefits outweigh the risks ca. 18,000 times.

Taking into account these factors, LUC UK selected a long review period of 12 years. LUC Group has developed an R&D plan consisting of five phases, which are discussed in further details in Chapter 4.1.3 in the AoA-SEA report of Use 1 of this application.

MOCA use in the manufacture of cast polyurethanes is intermediate use as per Article 3(15) of the REACH Regulation

LUC Group considers that its use of MOCA in the manufacture of polyurethane as described in this application fulfils the definition of intermediate use as per Article 3(15) as clarified in the ruling of the 2017 European Court of Justice ruling in case C-650/15 P. However, as it is not yet clear to LUC Group how to demonstrate this to the relevant authorities in the UK, it is submitting this application as a contingency measure.

When MOCA was proposed for inclusion on the candidate list, it was stated in the Annex XV dossier[2] that MOCA use in the manufacture of polyurethanes was not an intermediate use based on a definition of intermediates given in the ECHA Guidance from 2010.[3]

Specifically

> *According to the guidance on intermediates (ECHA 2010) document a substance should not be regarded as intermediate as soon as the main aim of the chemical process is not to manufacture another substance, but rather to achieve another function, specific property, or a chemical reaction as an integrated part of producing articles (semi-finished or finished). In accordance with this statement, the end use described above and the use as curing agent described in section 2.2.1 cannot be regarded as use of MOCA as intermediate. Similarly, it appears not possible to consider the use of MOCA as a cross-linking agent as use of the substance as intermediate.*

Based on this understanding, an upstream application was submitted to cover downstream users of MOCA as a chain-extender/curing agent in the manufacture of polyurethanes.[4] LUC Group is a downstream user of MOCA covered by this upstream application under transitional arrangements. However, in October 2017, the European Court of Justice has ruled in Case C-650/15 P that ECHA in its 2010 definition on intermediates has added a condition that is not in the legal text.[5] Specifically

> *Article 3(15) of that regulation contains no additional criterion allowing a differentiation to be made according to whether that purpose was primary or secondary in nature or examination of whether or not the chemical process by which one substance is transformed into another is indistinguishable from the end use for which that substance is intended.*

In this ruling, the Court found that by failing to classify acrylamide, in the context of the process of transformation into polyacrylamide for grouting purposes, as an 'intermediate', the General Court, by adding a condition that is not laid down in Article 3(15) of the REACH regulation, misinterpreted that provision.

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[2] The documents are available on the ECHA website at https://echa.europa.eu/fi/registry-of-svhc-intentions/-/dislist/details/0b0236e180e49371

[3] ECHA Guidance on Intermediates, V.2, 2010, available at https://echa.europa.eu/guidance-documents/guidance-on-reach

[4] Details of the application are available on the ECHA website at https://echa.europa.eu/applications-for-authorisation-previous-consultations/-/substance-rev/15329/term?_viewsubstances_WAR_echarevsubstanceportlet_SEARCH_CRITERIA_EC_NUMBER=202-918-9&_viewsubstances_WAR_echarevsubstanceportlet_DISS=true

[5] Judgment of the Court (First Chamber) of 25 October 2017, Polyelectrolyte Producers Group GEIE (PPG) and SNF SAS v European Chemicals Agency, Case C-650/15, available at http://curia.europa.eu/juris/document/document.jsf?text=&docid=195945&pageIndex=0&doclang=EN&mode=lst&dir=&occ=first&part=1&cid=596449

Considering this ruling in the context of MOCA use in the manufacture of polyurethane, MOCA use also fulfils the definition of intermediate use and the statement to the contrary given in the Annex XV dossier is based on criteria that are not in the legal text. Following the rationale given in the court decision,[5] three conditions need to be fulfilled for the use of a substance to be capable of being regarded as use of an intermediate. The first of those conditions concerns the intended purpose at the time of the manufacture and use of a substance as an intermediate, which consists of transforming that substance into another. The second condition concerns the technical means by which that processing takes place, namely a chemical process known as 'synthesis'. The third condition restricts the scope of the definition of 'intermediate' to uses of a substance which remains confined to a controlled environment, which may be either the equipment within which synthesis takes place, or the site in which the manufacturing and synthesis takes place or to which that substance is transported, 'site' being defined in Article 3(16) of the REACH Regulation as a 'single location' in which infrastructure and facilities are installed.

Applying these criteria to the use of MOCA in the manufacture of PU, it can be seen that as the intended use at the time of the manufacture and use of MOCA is to transform it into another substance, the first of these three conditions is satisfied. MOCA is used in the manufacture of another substance during which it is itself transformed into that other substance, namely polyurethane. The use of MOCA to manufacture polyurethane at LUC Group's site also fulfils the other two criteria; namely that the reaction can be described as synthesis and is confined to a controlled environment.

Consequently, LUC Group consider their use of MOCA to be intermediate use and that authorisation is not required for this use. The reasoning is given below.

LUC Group has also considered the draft update of the ECHA guidance on intermediates that was made available in March 2022.[6] The guidance update was initiated in light of the court ruling and gives the three conditions that must be fulfilled for a use to be considered "intermediate use".

Considering the 1st condition, the draft guidance states that this condition is fulfilled when the following conditions are met;

- *it can be demonstrated that the intermediate substance has been manufactured and used with the intention to be transformed into another substance*
- *it can be demonstrated that the intermediate substance has been actually transformed into another substance*
- *Information can be provided on the identify the other substance into which the intermediate has been transformed*

These conditions are fulfilled as MOCA is manufactured is manufactured and supplied to be used as a reactant in the manufacture of polyurethanes. MOCA is consumed in the reaction to yield a polymer substance, polyurethane.

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[6] Draft presented at the 44th Meeting of Competent Authorities for REACH and CLP (CARACAL) 23 March 2022 under agenda point 4.3 Open session on "Intermediates – ECHA revised guidance document and REACH revision"

Considering the 2nd condition, the draft guidance states it is fulfilled when the following conditions are met;

- *it can be demonstrated that the transformation of the intermediate substance into another substance (link to condition 1) takes place in the context of a chemical process and a specific equipment is used for this process;*
- *that chemical process is a 'synthesis' process;*
- *it can be demonstrated that, to avoid risks for human health and the environment, the intermediate substance remains contained after its manufacturing throughout the whole chemical process. The containment of the intermediate substance must be ensured by technical means at the site (for an on-site isolated intermediate) or during the transport/storage at the site where it is later used (for a transported isolated intermediate).*

These conditions are fulfilled as MOCA is used at an industrial site in dedicated equipment for the manufacture of polyurethanes. The process is synthesis whereby the reactants including MOCA are transformed to a polymer substance, polyurethane. MOCA is transported from the site of manufacture (in Suzhou, China) to the site of use in sealed drums. The drums are solely opened in a glove box and fed via a closed system to a casting machine.

Considering the 3rd condition, the draft guidance states that this condition is fulfilled when the following conditions are met;

- *it can be demonstrated that the equipment or site where the chemical processing takes place is a controlled environment ensuring the confinement of the intermediate substance through technical means avoiding risks for human health and the environment (link to condition 2) where transformation to another substance takes place (link to condition 1);*
- *it can be demonstrated that in case the intermediate substance is removed from the equipment during the chemical process, the intermediate substance remains confined to a controlled environment through technical means avoiding risks for human health and the environment (link to condition 2).*

These conditions are fulfilled as MOCA is used at an industrial site in dedicated equipment where technical and organisation controls are in place to avoid risks to human health and the environment. For the automated polyurethane production process, MOCA is confined to the casting machine. For the semi-automated process, liquid MOCA is dispensed from the storage unit in the casting machine to a vessel, after which it is transferred to a closed reaction vessel where MOCA reacts with the other reactants under stirring to yield polyurethane.

In conclusion, for the reasons outlined above MOCA use in the manufacture of polyurethanes as described in this application fulfil the criteria to be considered as intermediate use. As it is not yet clear how LUC Group would document its decision, it is submitting this application as a contingency measure.

2. AIMS AND SCOPE

2.1. Aims of the analysis

LUC (UK) Limited (referred to as LUC UK from here on) is producing high-performance hot cast polyurethane elastomers using 2,2′-dichloro-4,4′-methylenediamine ("MOCA"), which is classified as carcinogen (Carc. 1B) under UK REACH. MOCA is not considered to be a threshold carcinogen and, therefore, the adequate control of risks arising from its use cannot be demonstrated in accordance with Annex I, section 6.4 of UK REACH, for the uses applied for. LUC UK is preparing this Application for Authorisation covering two uses to ensure continuity of their business and providing suitable polyurethane products to their current customer base because LUC UK is vulnerable to their customer base switching to suppliers outside the UK.

LUC UK is a downstream user of MOCA in the supply chain of Suzhou Xiangyuan New Materials Co., Ltd. (Suzhou) and their use of MOCA is currently covered by the application submitted under EU REACH by REACHLaw acting as only representative for Suzhou under Brexit transitional arrangements, as the Commission has not yet taken a decision on the application. LUC Group submitted a downstream user application to cover its use at 4 sites in the EEA on 20.05.2020 and the ECHA opinion on this application was issued to the Commission for decision making on 28.07.2021. Details of the application are available on the ECHA website. As this application was submitted before the end of the Brexit transition period, it included also use at the UK site. Since the 01.01.2021, the UK site is now under UK REACH and the application submitted under EU REACH is not relevant. LUC UK is submitting this application to cover use at the UK site.

The aim of this combined Analysis of Alternatives (AoA) and Socio-economic Analysis (SEA) report is to: 1) demonstrate that no suitable alternative substances or technologies are implementable by LUC UK before the sunset date; and 2) to demonstrate that the socio-economic benefits of the continued use of MOCA outweigh the risks to human health and environment.

In particular this document will provide:

1. Details of the specific polyurethanes manufactured using MOCA
2. Details of the technical requirements of these products (heavy-duty rollers, tensioner pads and spring blocks) used in the offshore energy and renewables sectors
3. The rationale for why there are no suitable alternatives available at this time
4. The benefits from continued use exceed the monetised risks to workers significantly

This Analysis of Alternatives (AoA) and Socio-economic Analysis (SEA) report has been prepared by LUC (UK) Limited as the applicant, addressing its of MOCA in the UK. The substitution strategy of LUC Group is discussed in the AoA-SEA report of Use 1 of this application.

2.2. LUC Group

For the description of LUC Group, please see Chapter 2.2 in the AoA-SEA report of Use 1 of this application.

2.3. Supply chain

For the description of the supply chain, please see Chapter 2.3 in the AoA-SEA report of Use 1 of this application.

2.4. Scope of the analysis

2.4.1. Geographical scope

For the description of the geographical scope, please see Chapter 2.4.1 in the AoA-SEA report of Use 1 of this application.

2.4.2. Temporal scope

For the description of the temporal scope, please see Chapter 2.4.2 in the AoA-SEA report of Use 1 of this application.

3. ANALYSIS OF ALTERNATIVES

3.1. SVHC use applied for

3.1.1. Introduction to cast polyurethane and their chemistry

For an introduction to PU chemistry, please see Chapter 3.1.1 in the AoA-SEA report of Use 1 of this application.

3.1.2. Description of the functions(s) of MOCA and performance requirements of associated products

3.1.2.1. Description of the technical function provided by MOCA

The technical function of MOCA is the same in both of the uses covered by this application. Please refer to Chapter 3.1.2.1 of Use 1 for additional information on MOCA's technical function.

3.1.2.2. Properties of MOCA

For a description of the properties of MOCA, please see Chapter 3.1.2.2 in the AoA-SEA report of Use 1 of this application.

3.1.2.3. Description of the technical requirements that must be achieved by the products made with MOCA

PU products cured with an alternative curing agent must have the same technical properties as the TDI/MOCA PU products in order to be used in the offshore energy and renewables sectors. In some cases, alternative curing agents have been shown to perform as well or even better than MOCA in regard to an individual technical property however, none of the alternative PU material has the same high-performance and high reliability characteristics that a MOCA PU material has.

For the parts covered by this use, the most important technical requirements relate to material properties as follows:

- **Mechanical strength:** A high mechanical strength is necessary to handle the loads that are applied on the PU-covering. The loads are extremely high especially in the renewable industry but also in the offshore energy industry. A PU with insufficient mechanical strength will powder or crack rendering the part unusable.
- **Dynamic load bearing capacity:** Parts have to withstand extreme dynamic loads in these industries. A PU with insufficient dynamic load bearing capacity will build up temperature and melt (degrade) or start cracking/fail.
- **Deflective/compression behaviour:** Parts need to have very specific and accurate compressive and deflective behaviour, which does not change with time.
- **Fatigue:** Fatigue behaviour is an important factor in terms of product life and durability. Parts with low fatigue resistance will need to be changed more often.
- **Coefficient of friction:** A high coefficient of friction is important for tensioner pads to maintain grip of the pipe or cable. Insufficient friction can lead to accidents, loss of pipe/cable, damage to equipment and harm workers.

For driven heavy duty rollers (i.e. powered by a motor), a high coefficient of friction is also required as they need to maintain a good grip on the pipes, cables and monopiles.

For non-driven heavy duty rollers, CoF is not a key requirement.

- **Adhesion:** Adhesion is important as a strong bond between the substrate and the polyurethane must be formed. A weak bond between the two materials will lead to failures, equipment damage and the part will need to be replaced.
- **Resistance to environmental factors**: Parts need to excel in harsh environmental and meteorological conditions. They must withstand frost as well as high temperatures (up to 60°C) and high humidity. In addition, products must be resistant to alkaline and acidic conditions, mineral oils and sea water.
- **Reliability:** It represents the likelihood of the product to perform its intended function for the defined period of usage and under the defined operating conditions in a manner that customer requirements are either met or exceeded.

  As is clear from the descriptions of the pipe and cable laying and monopole installation for wind turbines, LUC UK's PU products have high reliability requirements for offshore energy and renewable applications. This is due to several factors:

  - The remoteness of the location where the part is used. The ships work dozens or hundreds of kilometres from the shore. Accidents forces the ships to interrupt its ongoing operation and return to port, which costs energy and causes delays in the project and financial loss.
  - The dangers associated with a failure are high. Failure of a component (e.g. the gripper releases its grip on the monopole) could cause tremendous damage to the ship and lead to injury or loss of life. The poor accessibility of the location is a compounding factor for rescue operations.

  Proven reliability is therefore a critical parameter for LUC UK's products thus, the PU products cured with an alternative chain-extender must be as reliable as MOCA-cured PU products. When purchasing LUC UK's products, the Applicant's clients are expecting a highly reliable product. If LUC UK fails to deliver such a product, LUC UK's clients will switch to non-UK moulders who can continue the use of MOCA to obtain the reliable products they have the confidence in. In this case LUC UK would lose its customer base, which would have a negative economic impact on LUC UK's business.

  Safety plays an important role in the offshore energy and renewable industries due to the high risks involved with these applications. Each customer will have its own safety protocols for accepting new products.

For heavy duty rollers, the key technical requirements are: mechanical strength, dynamic load bearing, a high CoF (only for driven rollers), adhesion, fatigue, resistance to environmental factors and reliability.

For friction or tensioner pads, the key technical requirements are: mechanical strength, deflective/compression behaviour, fatigue, high coefficient of friction (especially at higher contact pressures), adhesion, resistance to environmental factors and reliability.

For spring blocks, the key technical requirements are: mechanical strength, dynamic load bearing, deflective/compression behaviour, fatigue, resistance to environmental factors and reliability.

All these properties in combination contribute to the quality and success of LUC UK's high-performance PU products in these sectors of use. The material properties are based on customer specifications for the products covered by this use. Therefore, non MOCA-based PU products need to fulfil these criteria to be considered "suitable".

The technical requirements listed above are used in this AoA to assess the performance of alternative PU materials compared with their TDI/MOCA counterparts. For quantitative definitions of the technical requirements (including minimum, maximum and typical values for the technical properties), please refer to Table 8 in Chapter 3.2.4 in the AoA-SEA report of Use 1 of this application. Resistance to environmental factors is not assessed as the curing agent does not have an influence on this property. The type of polyol used in the prepolymer and the use of certain additives affect the resistance to environmental factors.

3.1.3. Market analysis of products manufactured with MOCA

3.1.3.1. Description of the products resulting from the use of MOCA

LUC UK's MOCA based high-performance PU product portfolio for Offshore and Renewable Energy sectors comprises of 3 different product types:

I. Heavy duty rollers
II. Friction or tensioner pads
III. Spring blocks

These products are used for offshore installation work, in pipe and cable laying equipment or equipment for the manufacture and installation of monopiles (part of a windmill structure, see renewable energy section in Chapter 3.1.3.1.1 for detailed information).

In general, for all three product types, the parts are made to order for the vessel or project where they will be used. The shape and size of the part are determined by the customer's specifications. LUC UK's high-performance PU products are required to perform to specification for several years in the harsh weather conditions of offshore applications, resisting wear while maintaining optimum strength, flexibility and friction properties. Currently, there is no established alternative to TDI/MOCA PUs that customers trust for these applications. For the three product types, it can be said that all are used in harsh environments that have high-performance and reliability requirements meaning that high-performance material is needed.

I. Heavy duty rollers

Heavy duty rollers are typically medium to large sized rollers, with diameters in the range of 0.3-1.5 m and lengths in the range of 0.5-2 m. These rollers usually consist of a steel roller body with a polyurethane covering of approximately 2.5-10 cm thickness. Figure 2 and Figure 3 show examples of such rollers.

The primary function of these rollers is to convey pipes or cables on board the vessel and to deploy pipes or cables into the sea. The cover material on the rollers must be elastic in nature to avoid damage to the pipe or cable. High-performance PU is needed as the loads applied to these rollers can be very high, the rolling resistance of the material needs to be low and the material has to be suitable for the harsh marine environment.

Figure 2. Example of heavy duty rollers ready for shipping. The dark coloured layer is the polyurethane. The steel roller body is in red

#A

[redacted]

Figure 3. Heavy duty rollers (in black) on a pipe laying stinger

<u>II. Friction or tensioner pads.</u>

Friction or tensioner pads usually consist of a steel base with a 2-6 cm polyurethane layer on top. Figure 4 and Figure 5 show some examples of pads. The primary function of the polyurethane is generating sufficient friction between the pad and the pipe, cable or monopile. The compressive and shear loads can be very high and the environment can be very harsh. Thus, in addition to having a high coefficient of friction, the polyurethane material also has to be suitable for these circumstances. See Figure 7 for a schematic of where the pads are used.

#A

[redacted]

Figure 4. Tensioner pads (S-lay) with a black coloured polyurethane layer

#A

[redacted]

Figure 5. Tensioner pads (J-lay). The polyurethane layer is yellow

III. Spring blocks

Spring blocks are used in the same equipment as the tensioner pads. These are usually polyurethane blocks with various geometries, specifically designed to achieve an exact defined deflection at a certain compressive load. This exact deflection also has to be constant over time, without being significantly impacted by fatigue and by the marine environment. Figure 6 shows an example of a spring block.

Figure 6. Spring block

3.1.3.1.1. Sectors of use

Offshore pipe laying

Historically, the offshore pipe laying sector consisted primarily of the installation of offshore pipelines for the traditional Oil & Gas industry. Although this is no longer a growing market, there will still be a demand for these products in the future, both for the installation of new projects as well as for decommissioning work.

In this section, LUC UK gives an overview of pipe laying to give contextual information on why products with high reliability and high-performance are necessary.[7] Pipes used in offshore applications to transport gas or oil are installed using a specific pipe-laying vessel. Two methods are typically used in the installation: the S-Lay or J-Lay installation method. Tensioner pads are key components of the machinery used in the S-Lay method of pipe-laying. In this method, as shown in Figure 7, a supporting structure protruding from the vessel (referred to as a stinger) is used to lay the pipeline under water. The stinger, which is mostly submerged, controls the first bend (the overbend) of the pipeline. The pipe also forms a second bend (the sag bend) where it touches the seabed. There is tremendous pressure applied on this bend arising from the pipe's submerged weight that needs to be counterbalanced by tension applied via tensioner pads on board of the vessel. **Tensioner**

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[7] For additional information on pipe-laying process, please see the following videos:

- Part 1: https://www.youtube.com/watch?v=EyrdjqEiTZc (9:10)
  - From 0:40 to 1:45, a render of a pipe-laying vessel can be seen. Heavy duty rollers and tensioner pads can be seen on multiple occasions.
  - At 2:10 a pipe-laying ship is showed along with its specifications.
  - Tensioner pads can be seen at 3:30 (top-most part of cradles), 4:00 and very briefly in other parts of the video.
  - Heavy duty rollers can be seen at 4:35-5:00, 5:43-5:49, 7:03-7:08 and 8:03-8:20.
- Part 2: https://www.youtube.com/watch?v=Dc2i06331qQ (9:39)
  - Tensioner pads can be seen at 0:27-0:50, 1:52-2:02, 3:00-3:14, 4:19-4:40, 4:51-4:54, 5:00-5:09, 5:51-5:56 and 6:04-6:06.
  - Heavy duty rollers can be seen at 4:51-4:54, 7:30-7:49 and 7:55-8:50 (rollers on the stinger).

pads are therefore critical in preserving the integrity of the pipes and a successful installation of subsea oil and gas pipelines.

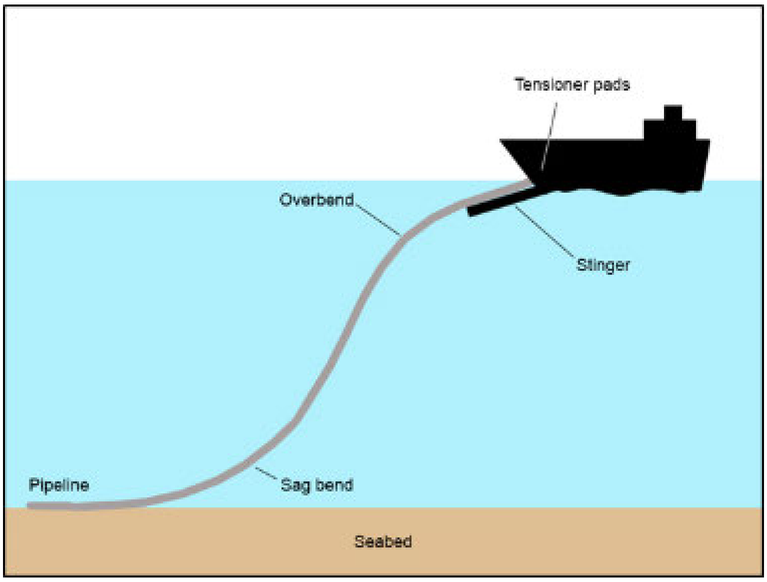

Figure 7. Principle of the S-lay installation method. Tensioner pads are inside the vessel. Heavy duty rollers are situated on the stinger and inside the vessel

The J-Lay installation method is preferred in areas with very deep waters. In the J-Lay pipe-laying, as shown in Figure 8, the pipeline is lowered into the water using a nearly vertical ramp. Here as well, the tensioner pads are critical to control the sag bend and prevent damage to the pipe.

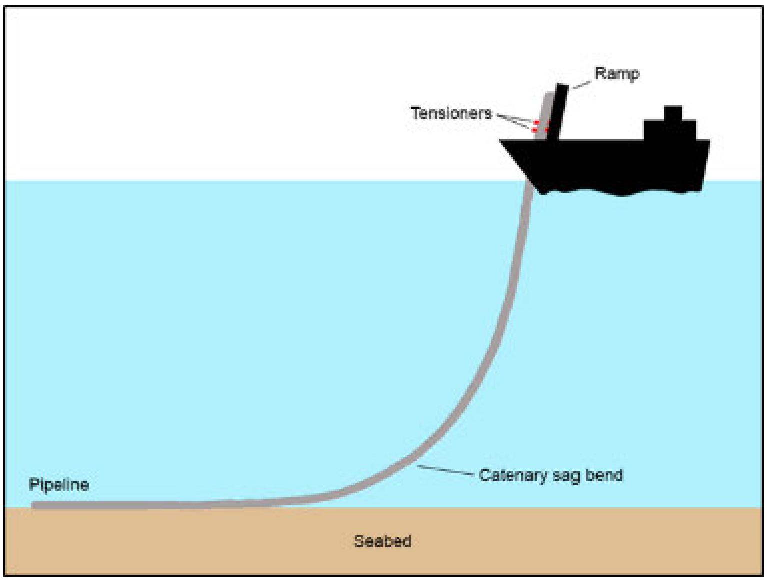

Figure 8. Principle of the J-Lay installation method. Heavy duty rollers and tensioner pads are situated on the ramp

In both methods, **heavy duty rollers** are used either on deck and on the stinger in the S-Lay method or on the ramp in the J-Lay method to safely move the pipes for welding. High-performance PU is required to move the pipes safely without damaging them. Damaged pipes pose a severe safety and environmental risk.

The tensioner pads are even more critical. Insufficient friction or loss of integrity of the pads due to insufficient strength could not only damage of the pipe, but also to lead to complete loss of the pipe. This is a severe safety risk, **as this could lead to fatalities and ultimately even loss of an entire vessel.**

Both the rollers and tensioner pads are used in harsh environments where high reliability and high-performance are critical.

Renewable Energy

A growing and more recent application for LUC UK's high-performance PU products is the installation of offshore wind parks, as a source of renewable energy, as shown in Figure 9. LUC UK's products are mainly used for the manufacture, shipping and installation of monopiles, which are the foundations of wind turbines. As wind turbines need to be connected to the power grid, extensive cable laying work are required. The equipment used for cable laying is also used for pipe laying.

Figure 9. Offshore wind park showing wind turbines as well as a substation used to connect the turbines to the power grid

Figure 10 shows a basic configuration of an offshore wind turbine. The wind turbine standing on a transition piece (yellow) with underneath a foundation pile, or a so called monopile. Monopiles can nowadays typically be up to 100 meters long, have a diameter of up to 11 meters and a weight of about 1500 tonnes. The limit has not been reached yet, the turbines keep getting bigger, as well as the monopiles, as can be seen in Figure 11. Therefore, also the equipment keeps getting bigger and the challenges for the PU heavy duty rollers keep increasing.

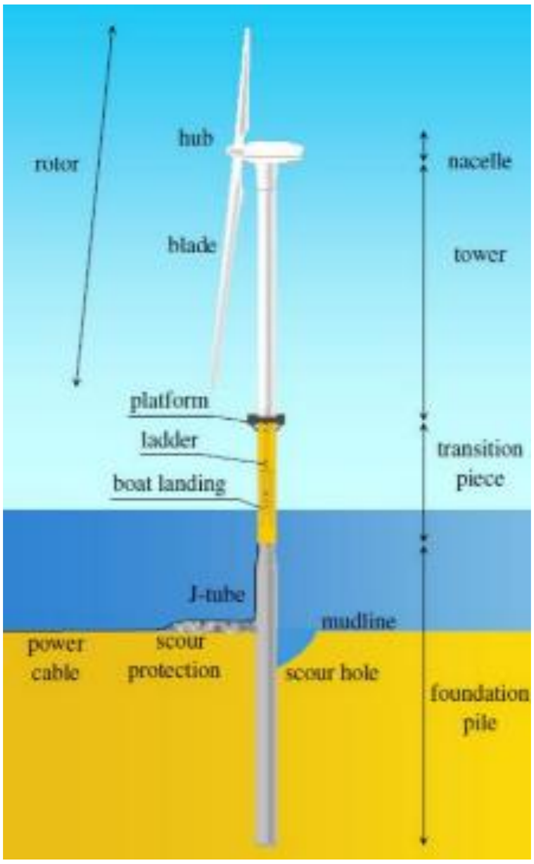

Figure 10. Typical configuration of an offshore wind turbine[8]

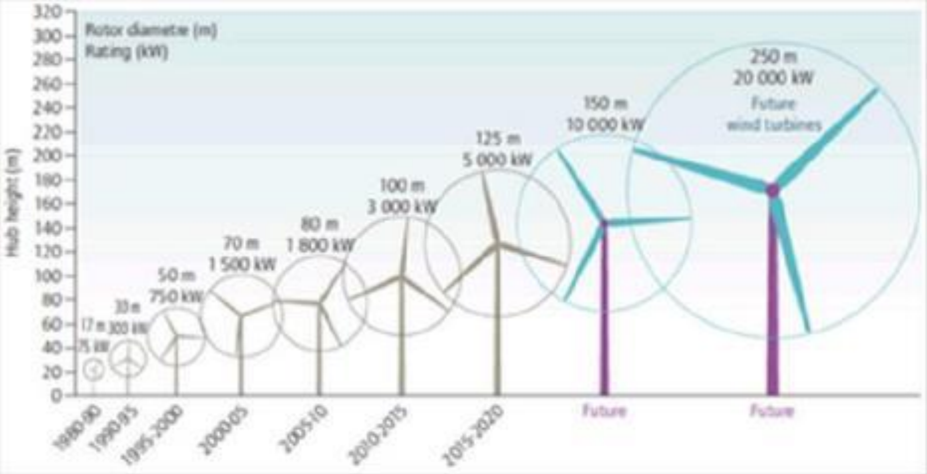

Figure 11. Increase in size of offshore wind turbines

Figure 12 shows a monopile and Figure 13 shows a monopile on top of a heavy duty roller during its manufacture.

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[8] Hoeksema, 2014

Figure 12. Monopile being transported out of manufacturing facility

#A [redacted]

Figure 13. Monopile on a heavy duty roller

The monopiles are placed in a cradle on board of a vessel when they are transported from the manufacturing location to the offshore installation site (Figure 14). The cradle is equipped with high-performance polyurethane friction pads that need to achieve a certain minimum coefficient of friction at a high compressive load (Figure 15). Insufficient friction could lead to the monopile starting to slide during transport. This is as severe safety risk as it could lead to the loss of the monopile or even cause the ship to sink. For this reason, customers have high reliability and high-performance requirements of the products used.

#A [redacted]

Figure 14. Monopiles loaded into cradles on-board of a vessel

#A [redacted]

Figure 15. Monopile on PU friction pads (under the red arrows)

During installation, the monopile is upended and kept in position using a monopile gripper (Figure 16). The gripper is equipped with large heavy duty polyurethane rollers that need high elasticity and high load bearing capacity.[9]

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Figure 16. Monopile gripper fitted with heavy duty polyurethane rollers (in dark brown/black)

It is a massive engineering operation to install a wind turbine and to lay cables connecting it to the electricity grid. Offshore installation work requires extreme precision and various safety risks are involved. Therefore, the PU parts must be highly reliable, durable and behave in a predictable way to prevent disastrous accidents.

3.1.3.2. Market analysis

General market information, such as size and trend, regarding MOCA and PU products in the UK market was not found after extensive web search. However, information on global PU market was available. The global PU market was valued at over 39 M GBP in 2021, and the market is projected to register a compound annual growth rate (CAGR) of 5 % between 2022 and 2027.[10] Without more specific information, it is assumed that also the UK PU market follows the same type of future projection.

The size of LUC UK's market niche, the high-performance PU products used in the offshore and renewable energy sectors, is approx. [0.5-1.5 M] #B GBP in the UK. LUC UK has ca. 5 main competitors supplying PU products to the offshore and renewable energy sectors in the UK. LUC UK has a fairly good position in the supply of high-performance PU products in the UK market with a market share of [20-55] #B %. LUC UK's market share of the high-performance PU market is expected to grow because the number of new customers has been increasing as LUC UK is getting a share of the market where customers

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[9] For additional information on the installation of a monopile, please see the following video:

- https://www.youtube.com/watch?v=OcRqzT2uU6c (3:52)

[10] https://www.mordorintelligence.com/industry-reports/polyurethane-market

switch from competitors who offer non-MOCA PU products. The switch is due to the customers' dissatisfaction with the performance, quality and reliability of non-TDI/MOCA PU products offered by competitors since the sunset date for MOCA. Taking the above information into account LUC UK expects an annual growth rate of [8–16] #B % for its revenue in the foreseen future.

However, the high-performance PU market is vulnerable to extra-UK competition. If the use of MOCA is not permitted to manufacture the high-performance PU products, this will distort the market in that non-UK suppliers have a competitive advantage. LUC UK's customers can easily switch to non-UK moulders. As the finished PU products do not contain any MOCA, they are not affected by authorisation thus, non-UK moulders can continue freely to place their MOCA-cured products on the UK market. LUC UK has to compete with these non-UK moulders, which puts them in a vulnerable position in that at any time, LUC UK's customers may leave them for a non-UK moulder.

The TDI/MOCA high-performance PU products covered by this use (Use 2), are used for offshore installation work, in pipe and cable laying equipment or equipment for the manufacture and installation of monopiles. To assess the demand for the TDI/MOCA high-performance PU products, an overview of the offshore wind market in the UK is presented next.

Offshore wind market in the UK

The UK is the world leader in offshore wind, with more installed capacity than any other country, owning a quarter of the total global portfolio. The UK enjoys a long coastline with good wind speed and relatively shallow seabed, making it an ideal place to develop offshore wind farms. As a result, the largest wind farms and turbines in the world are being planned and installed alongside the UK coast. Renewable energies like wind are an important part of decarbonising the economy and slowing climate change. The UK government has set a legally binding target of "Net Zero" greenhouse gas emissions by 2050. In addition, the UK government plans to quadruple current offshore capacity to 40 GW by 2030. Offshore, the wind speed and direction are stronger and consistent, meaning it can generate more power. But until recently, offshore developments have not been cost-effective. Offshore wind, once relatively expensive compared to onshore wind or solar, has seen a sharp reduction in capital costs (in 2020, around 65% lower than five years ago). This cost reduction comes in part due to the use of much larger turbines and technological advances, such as development of lithium-ion batteries, an essential element in ensuring continuity of supply from weather-dependent sources. The offshore wind sector has matured rapidly over the past few years and it is now capable of providing a reliable supply with proven technology. The cost of new offshore wind has fallen by 50% since 2015 and it is now one of the lowest cost options for new power in the UK.[11] [12] [13] [14]

In 2020, the UK generated 75,610 gigawatt hours (GWh) of electricity from both offshore and onshore wind. This would be enough to power 8.4 trillion LED light bulbs. Individually, both offshore and onshore wind electricity generation has grown substantially since 2009.

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[11] https://www.ons.gov.uk/economy/environmentalaccounts/articles/windenergyintheuk/june2021

[12] https://www.renewableuk.com/page/WindEnergy

[13] https://www.bp.com/en/global/corporate/news-and-insights/reimagining-energy/offshore-wind-explainer.html

[14] https://www.trade.gov/market-intelligence/united-kingdom-offshore-wind-market

Wind energy generation accounted for 24% of total electricity generation (including renewables and non-renewables) in 2020; with offshore wind accounting for 13% and onshore wind accounting for 11%. Electricity generation from wind power in the UK has increased by 715% from 2009 to 2020. The offshore and onshore wind sectors generated almost 6 B GBP in turnover in 2019. Employment in offshore wind in the UK has increased significantly since 2015, with 7,200 full-time equivalent (FTE) employees in 2019.[11]

Offshore wind is already currently an important piece in the UK energy market but in the future even more important. The market is growing, and the government is backing it. LUC UK's products are used for equipment for the manufacture and installation of monopiles which demand is consequently growing. As the demand from offshore sector is increasing rapidly LUC UK is expecting [8–16] #B % annual growth rate.

3.1.4. Annual volume of the SVHC used

LUC UK currently uses 2 tons of MOCA annually. The highest forecast annual tonnage over the review period is 3.8 tons. The annual tonnage used in the risk assessment is 3.8 tons The monetised risk values were derived using this value.

The tonnage can be divided between the uses with the same percentage shares as other variables: 68 % for Use 1 and 32 % for Use 2. This accounts 1.22 tons as highest forecast tonnage for Use 2 in the 12-year review period applied for.

3.2. Efforts made to identify alternatives

The efforts made to identify alternatives discussed in this chapter are the efforts of LUC Group.

3.2.1. Research and development

LUC Group has carried out extensive R&D work to find suitable alternatives to MOCA since 2009. For additional information, please see Chapter 3.2.1. in the AoA-SEA report of Use 1 of this application.

The test methods used to test the alternatives are presented in Chapter 3.2.1.1 of Use 1 AoA-SEA report.

3.2.2. Consultations with customers and suppliers of alternatives

For a description of the consultations, please see Chapter 3.2.2 in the AoA-SEA report of Use 1 of this application.

3.2.3. Data searches

For a description of the data searches, please see Chapter 3.2.3 in the AoA-SEA report of Use 1 of this application.

3.2.4. Identification of alternatives

LUC Group has been testing alternatives for more than a decade in the aim to find a replacement to MOCA. Results of their testing including a description of the minimum requirements used as pre-selection criterion and a list of rejected alternative candidates are presented in Chapter 3.2.4 of the Use 1 AoA-SEA report (#A is not rejected for Use 2).

For this use, a pot-life of #Amin is considered a minimum for tensioner pads and spring blocks. For heavy duty rollers, the minimum pot-life is #Amin.

3.3. Assessment of shortlisted alternatives

In this chapter, the most promising alternative candidates for Use 2 products or most common replacements of MOCA according to raw material manufacturers are assessed in further details. All test data presented in this chapter result from the research and development efforts by LUC Group.

The following colour codes are used in this chapter to assess the availability, safety considerations, technical feasibility and economic feasibility of the shortlisted alternatives.

Table 2. Colour codes used for the assessment of alternatives

Colour	Definition
🟥	Requirement not met
🟨	Fulfilment of the criteria not clear
🟩	Requirement met

3.3.1. Like-for-like diamine alternatives

In this chapter, we assess like-for-like diamine alternatives: Addolink® 1604 and in blends. These alternatives are used with TDI-based prepolymers, similarly to MOCA.

3.3.1.1. Addolink® 1604

3.3.1.1.1. General description of Addolink® 1604

For a general description of Addolink® 1604, please see Chapter 3.3.1.3.1 in the AoA-SEA report of Use 1 of this application.

3.3.1.1.2. Availability of Addolink® 1604

For a description of the availability of Addolink® 1604, please see Chapter 3.3.1.3.2 in the AoA-SEA report of Use 1 of this application.

3.3.1.1.3. Safety consideration related to using Addolink® 1604

For a description of the safety considerations related to using Addolink® 1604, please see Chapter 3.3.1.3.3 in the AoA-SEA report of Use 1 of this application.

3.3.1.1.4. Technical feasibility of Addolink® 1604

The reactivity and processability of Addolink® 1604 are good.

<u>Ether prepolymer system:</u>

During their R&D work, LUC Group conducted comparative studies on MOCA and Addolink® 1604 as curing agents in a polyether TDI-prepolymer system. The results are presented in Table 3.

Table 3. Test results of the comparative study between PUs made with MOCA/TDI ether prepolymer and Addolink® 1604/TDI ether prepolymer[15] (#A for all redactions in the table)

			MOCA/TDI ether - [redacted]°A			TDI ether - [redacted]°A
Property	Standard	Unit	Min. value	Nominal	Max. value	Addolink® 1604
Hardness (23°C)	ISO 48-4	°A	[redacted]	[redacted]	[redacted]	🟩 [redacted]
Hardness (85°C)	ISO 48-4	°A	[redacted]	[redacted]	[redacted]	🟩 [redacted]
Tensile strength	ISO 37[1]	MPa	[redacted]	[redacted]	[redacted]	🟥 [redacted]
Elongation at break	ISO 37[1]	%	[redacted]	[redacted]	[redacted]	🟩 [redacted]
Tear resistance	ISO 34-1 method B, procedure b	kN/m	[redacted]	[redacted]	[redacted]	🟩 [redacted]
Rebound (23°C)	ISO 4662	%	[redacted]	[redacted]	[redacted]	🟩 [redacted]
Rebound (85°C)	ISO 4662	%	[redacted]	[redacted]	[redacted]	🟩 [redacted]
Abrasion	ISO 4649 method B	mm^3	[redacted]	[redacted]	[redacted]	🟥 [redacted]
Compression set						
70h/ 23°C	ISO 815-1	%	[redacted]	[redacted]	[redacted]	🟥 [redacted]
22h/ 70°C	ISO 815-1	%	[redacted]	[redacted]	[redacted]	🟥 [redacted]

[1] LUC Group uses 200 mm/min instead of 500 mm/min as test speed on the tensile tester.

As it can be seen from the table above, Addolink® 1604 cured PU has much lower tensile strength. A PU part having low tensile strength will break more easily when exposed to tension and this can be catastrophic if the break occurs at sea.

PU abrasion and compression set are also out of specifications although to a lower extent than tensile strength.

The deflective behaviour of the PU part during end-use can be predicted based on the stress-strain curve of the material (Figure 17). The stress-strain curve is generated based on the tests results of the ISO 37 test. In the graph, the x-axis (strain [%]) represents the amount of elongation the test part undergoes (the higher the percentage, the higher the elongation). The y-axis (stress [MPa]) represents the amount of force required for stretching the material (the higher the number, the higher the force). This difference in deformation profile translate into end-products behaving differently during end-use. If the difference is significant, the alternative part will perform more poorly in end-use as its deformation profile will not be adapted to its use. The area under the stress-strain curve is also of importance. The larger the area, the higher the toughness of the material.

As it can be seen from the picture below, the PU deflective behaviour is similar to TDI/MOCA PU when exposed to low tensile strength. When exposed to higher tensile stress, the PU made with the alternative systemal elongates more than MOCA PU.

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[15] Colour code: 🟩 = within specification limits, 🟥 = out of specifications. The same colour coding will be used in the rest of the application.

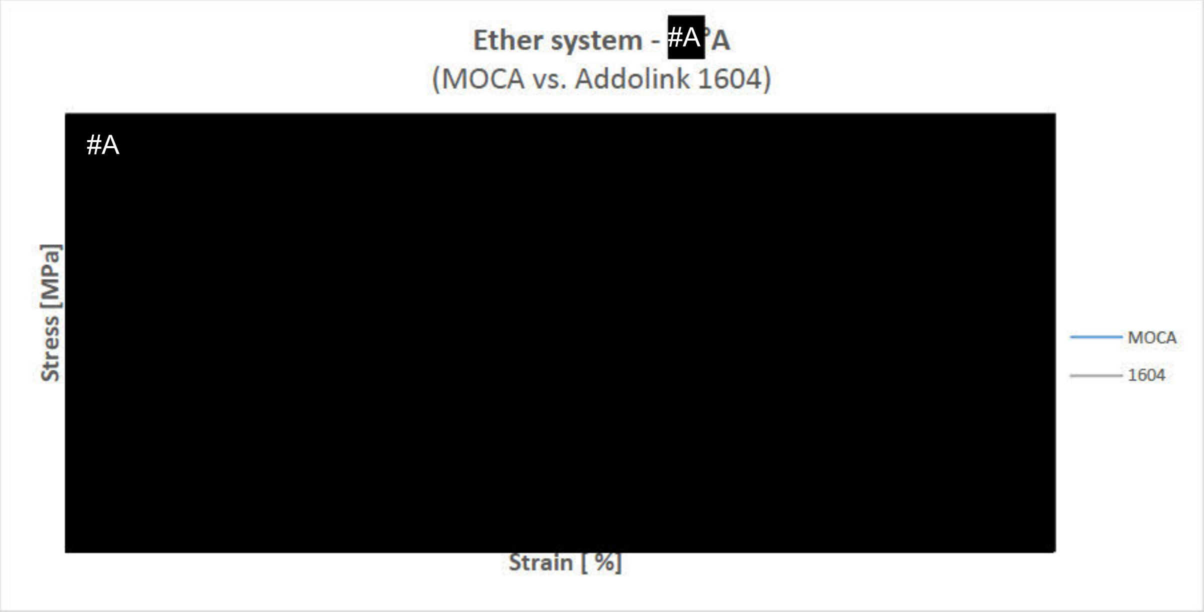

Figure 17. Stress-strain curves plotted from the results of ISO 37 test

The dynamic behaviour (i.e. dynamic load bearing capacity) of Addolink® 1604 cured PU was tested with LUC Group's Ride Simulator. The results are presented in Figure 18. The x-axis represents the load applied to the part while the y-axis represents the measured temperature of the PU covering. The higher the number, the more heat is building up in the PU material. The last vertical line represents the point where the dynamic load bearing capacity is reached and the material starts failing due to heat build-up or cracking.

As seen in the figure below, the PU made with the alternative system could not withstand as high of a load as MOCA cured PU and the material failed already when a load of [redacted] kg was applied. In comparison, MOCA cured PU failed at a higher load of [redacted] kg. Thus, there is an important difference in dynamic load bearing capacities between the two materials.

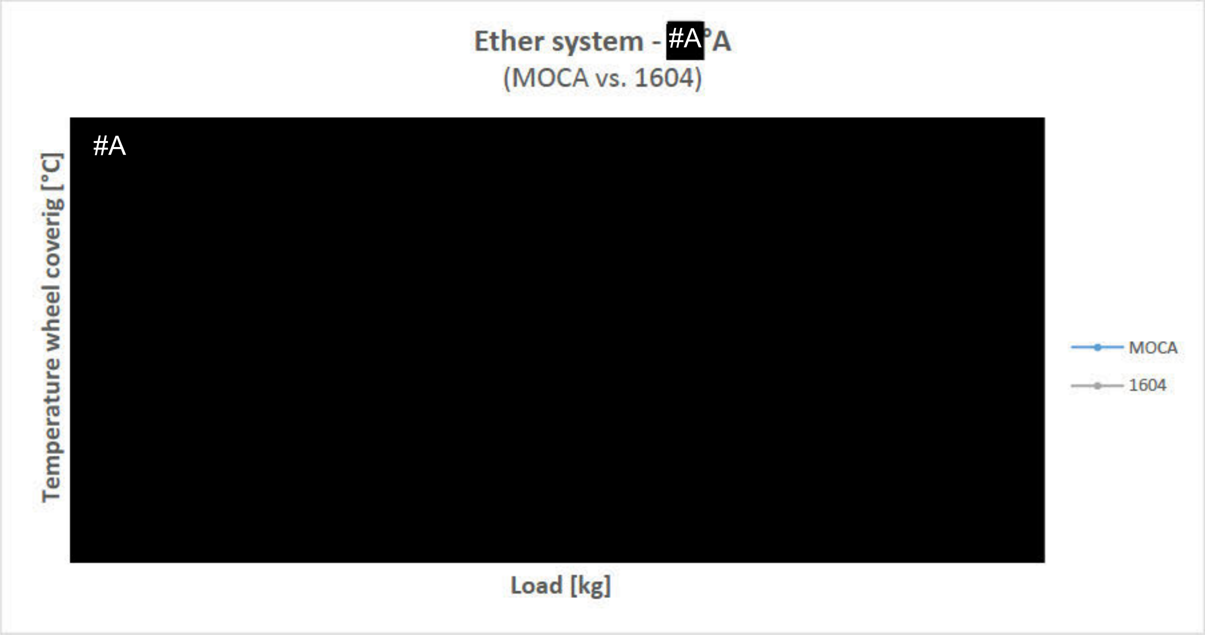

Figure 18. Test results showing the different dynamic behaviour of PU cured with Addolink® 1604 and MOCA

LUC Group also tested the CoF of the alternative PU using three different counter material: steel, stainless steel and 3-layer polypropylene (3L-PP). All are common materials used in Use 2 sectors.

In the figures, the CoF of the materials (y-axis) are represented as a function of contact pressure. The higher the force exerted on the material, the higher the contact pressure (e.g. when you press an object harder against a table, the contact pressure increases).

For tensioner pads and driven heavy duty rollers, high PU CoF is required to ensure that parts (e.g. monopiles, pipes) do not slip. Due to the high loads used in the applications covered by this use, the PU CoF at high contact pressures is particularly important. For non-driven heavy duty rollers, the PU CoF is not a key requirement.

The next 3 figures present the results of the CoF tests conducted on PUs made with the Addolink® 1604/TDI ether system. As it can be seen, the PU CoF is lower especially at higher contact pressures, where a reduction of approximately 0.1 in CoF can be observed with 3L-PP and stainless steel. A smaller reduction was observed with steel.

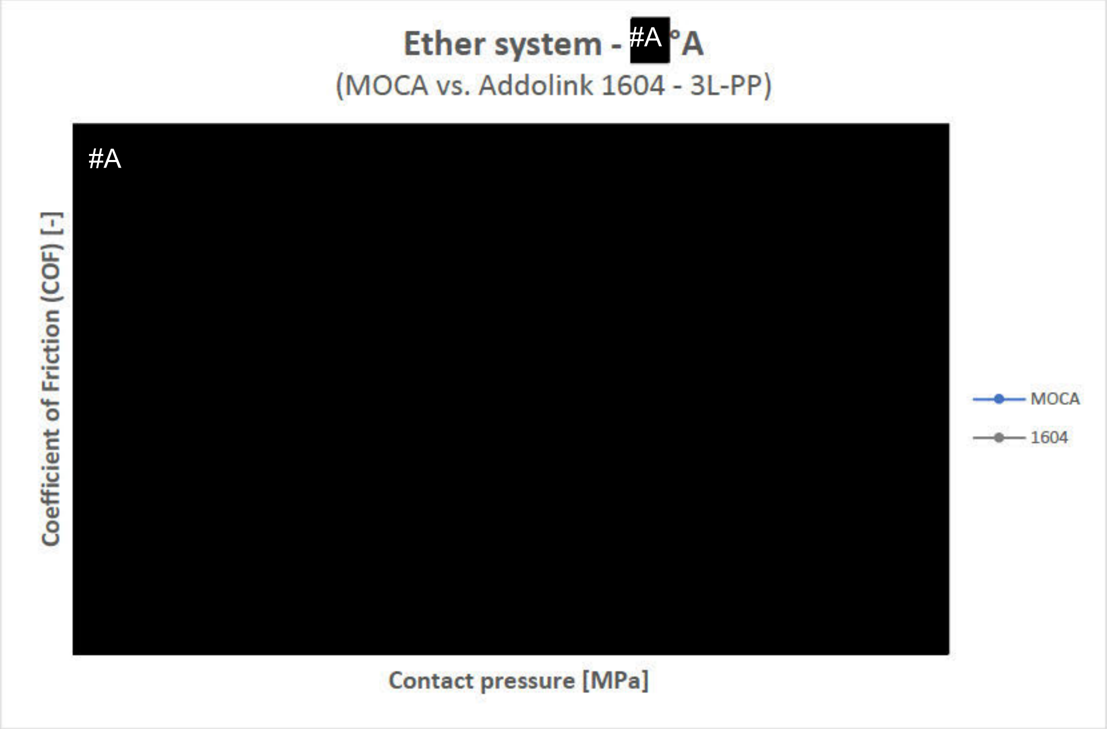

Figure 19. Results of the CoF test using 3-layer polypropylene

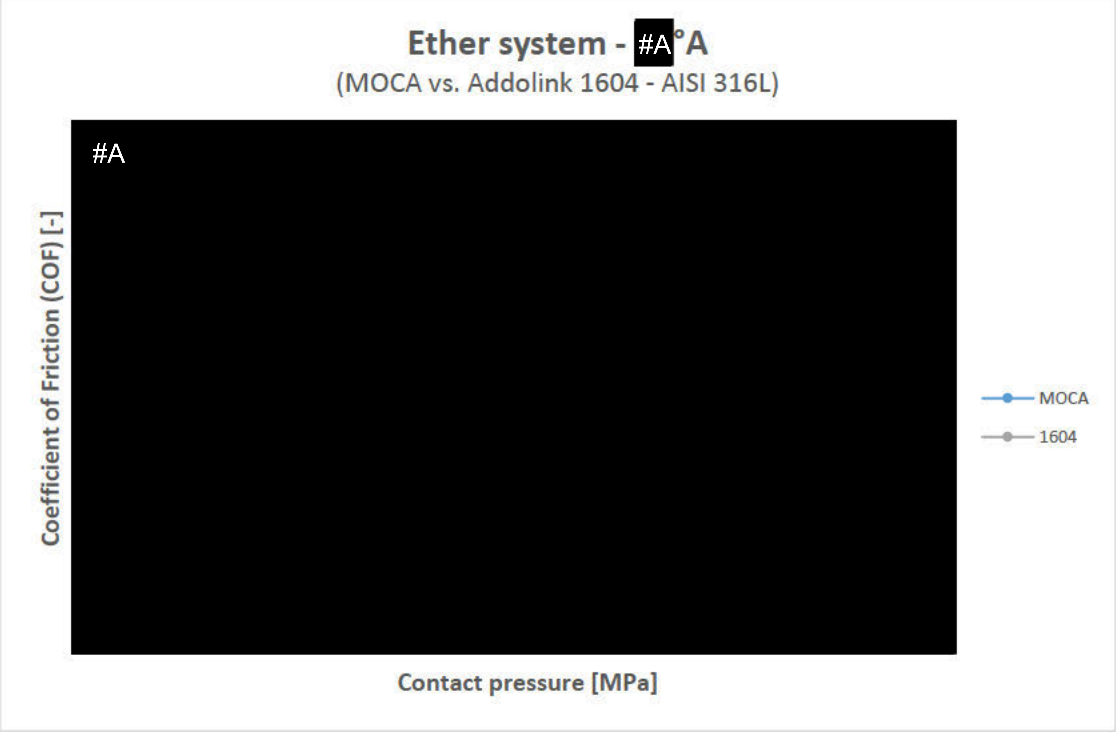

Figure 20. Results of the CoF test using stainless steel

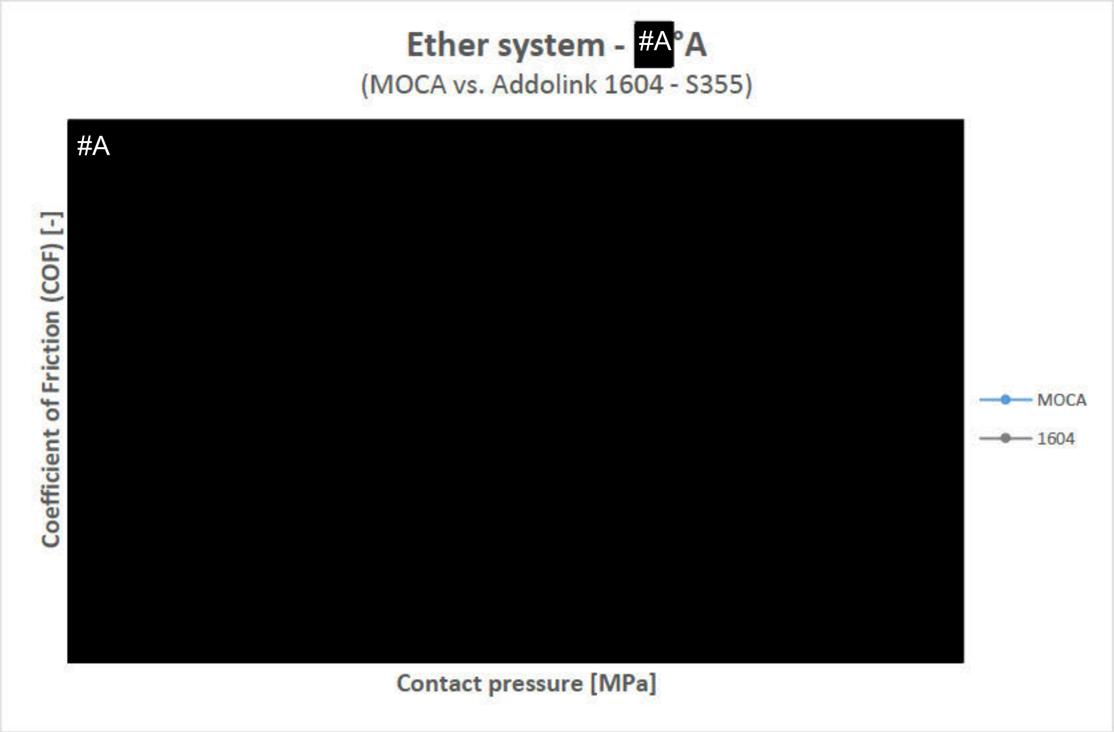

Figure 21. Results of the CoF test using steel

<u>Ester prepolymer system:</u>

LUC Group also tested the technical properties of Addolink® 1604 cured PU with a TDI ester prepolymer and compared them to MOCA cured PU. The results are presented in Table 4. The PU made with the alternative system had several properties that are not within specifications. PU tensile strength was lower and the retained more permanent deformation at room temperature than MOCA. Lastly, Addolink® 1604/TDI ester PU is more bouncy than MOCA PU (higher rebound).

Table 4. Test results of the comparative study between PUs made with MOCA/TDI ester prepolymer and Addolink® 1604/TDI ester prepolymer (#A for all redactions in the table)

			MOCA/TDI ester - [redacted]°A			TDI ester - [redacted]°A
Property	Standard	Unit	Min. value	Nominal	Max. value	Addolink® 1604
Hardness (23°C)	ISO 48-4	°A	[redacted]	[redacted]	[redacted]	[redacted]
Hardness (85°C)	ISO 48-4	°A	[redacted]	[redacted]	[redacted]	[redacted]
Tensile strength	ISO 37[1]	MPa	[redacted]	[redacted]	[redacted]	[redacted]
Elongation at break	ISO 37[1]	%	[redacted]	[redacted]	[redacted]	[redacted]
Tear resistance	ISO 34-1 method B, procedure b	kN/m	[redacted]	[redacted]	[redacted]	[redacted]
Rebound (23°C)	ISO 4662	%	[redacted]	[redacted]	[redacted]	[redacted]
Rebound (85°C)	ISO 4662	%	[redacted]	[redacted]	[redacted]	[redacted]
Abrasion	ISO 4649 method B	mm^3	[redacted]	[redacted]	[redacted]	[redacted]
Compression set						
70h/ 23°C	ISO 815-1	%	[redacted]	[redacted]	[redacted]	[redacted]
22h/ 70°C	ISO 815-1	%	[redacted]	[redacted]	[redacted]	[redacted]

[1] LUC Group uses 200 mm/min instead of 500 mm/min as test speed on the tensile tester.

In Figure 22, a stress-strain curve for both materials is presented. The deflective behaviour of Addolink® 1604 cured PU is comparable to MOCA cured PU.

Figure 22. Stress-strain curves plotted from the results of ISO 37 test

The test results obtained of the dynamic behaviour test are presented in Figure 23. The dynamic load bearing capacity of the alternative PU material was lower compared to MOCA PU ([redacted] kg vs [redacted] kg).

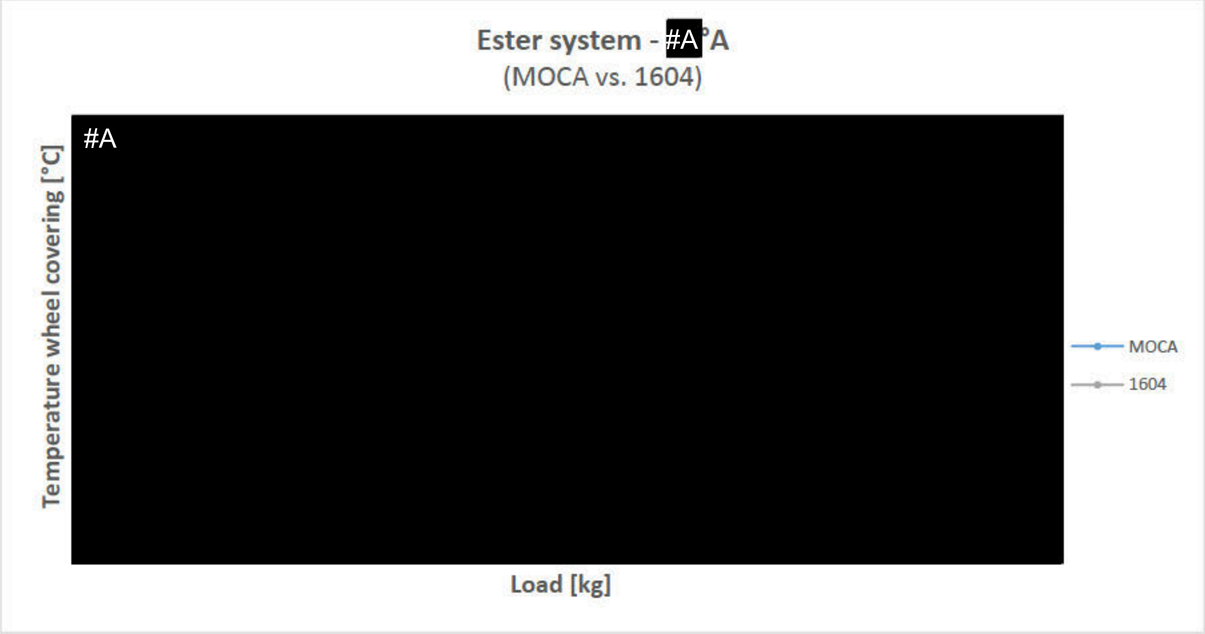

Figure 23. Test results showing the different dynamic behaviour of PU cured with Addolink® 1604 and MOCA

The results of the CoF tests are presented in the next three figures. An important reduction in CoF was observed from #A MPa with 3L-PP. The reductions in CoF were smaller with steel and stainless steel. Overall, PU made with Addolink® 1604 performs worse than MOCA cured PU at higher contact pressures.

Figure 24. Results of the CoF test using 3-layer polypropylene

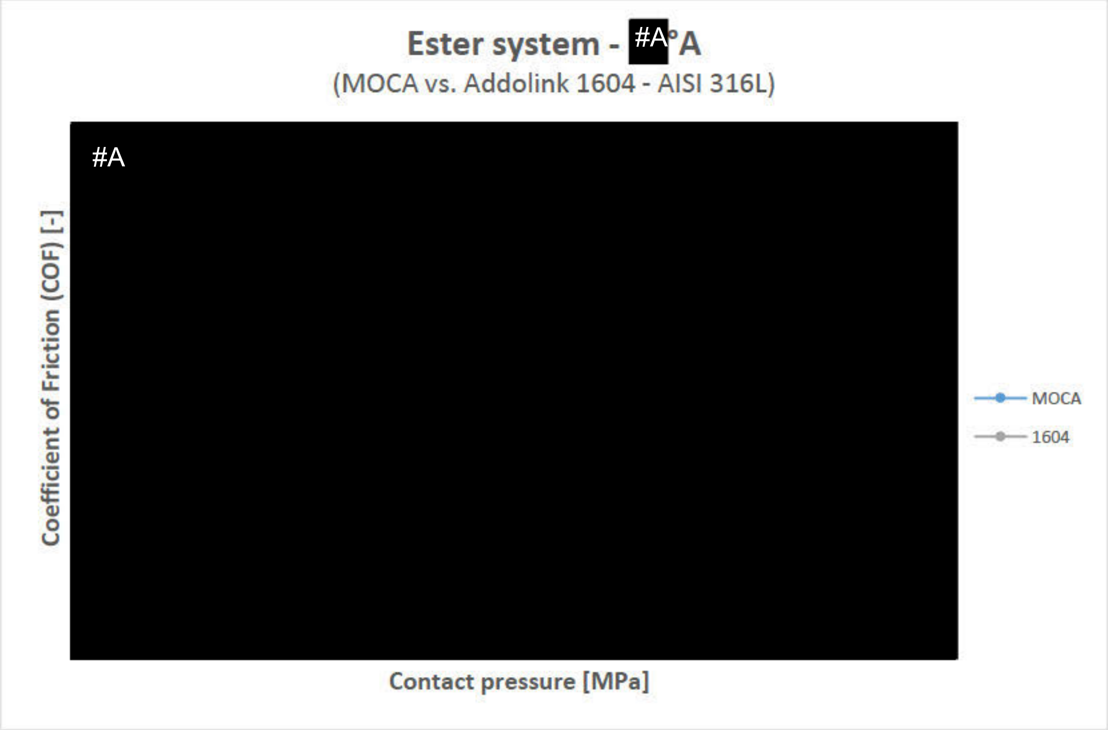

Figure 25. Results of the CoF test using stainless steel

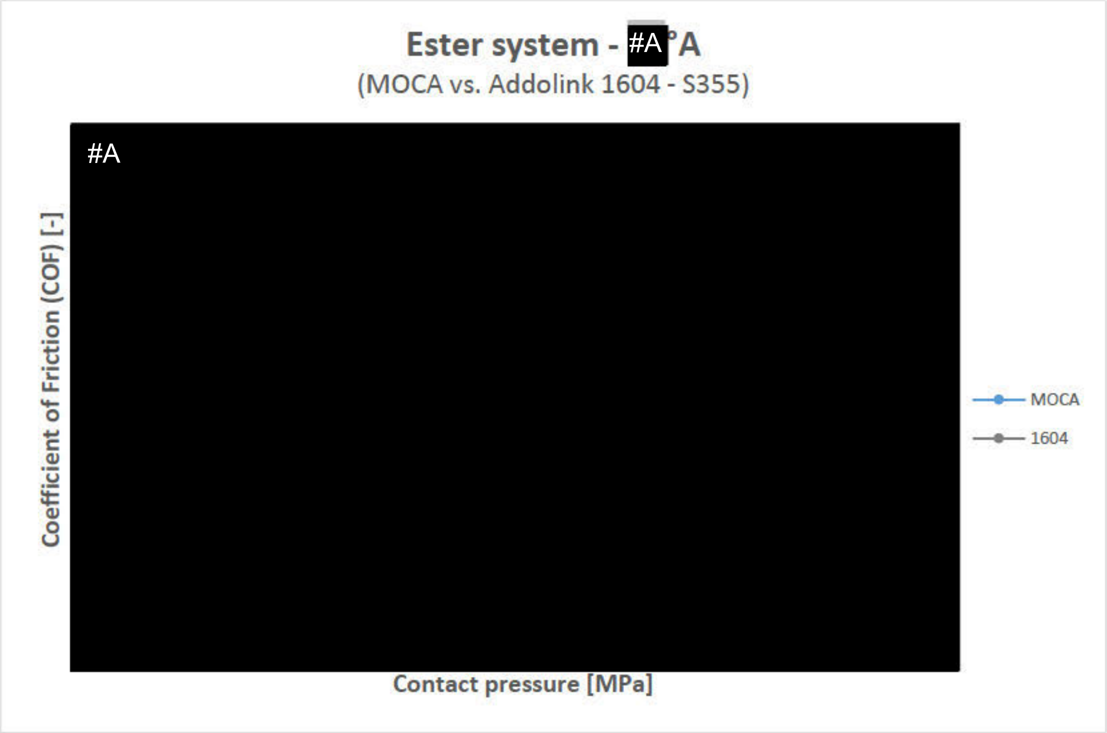

Figure 26. Results of the CoF test using steel

<u>Customer trials:</u>

LUC Group has conducted trials at customers' site where alternative PU parts were tested in end-use. Customers have reported that the alternative products have lower dynamic and fatigue properties.

Summary:

In terms of reactivity, Addolink® 1604 is the closest match to MOCA. The pot-lives of elastomers cured with Addolink® 1604 are similar or even higher than MOCA, which enables the production of large volume products. Thus, all the products covered by Use 2 can be casted when using this alternative.

A summary comparing the technical properties of PUs made with the MOCA/TDI and Addolink® 1604/TDI both in the ester and ether prepolymer systems is presented in Table 5. The alternative PU materials were out of specifications for some technical properties.

Table 5. Comparison of PU technical properties (MOCA vs. Addolink® 1604) (#A for all redactions in the table)

Property	MOCA/TDI ether - [redacted]°A Acceptable range	1604/TDI ether - [redacted]°A Test results	MOCA/TDI ester - [redacted]°A Acceptable range	1604/TDI ester - [redacted]°A Test results
Hardness (23°C)	[redacted]	🟩 [redacted]	[redacted]	🟩 [redacted]
Hardness (85°C)	[redacted]	🟩 [redacted]	[redacted]	🟩 [redacted]
Tensile strength	[redacted]	🟥 [redacted]	[redacted]	🟥 [redacted]
Elongation at break	[redacted]	🟩 [redacted]	[redacted]	🟩 [redacted]
Tear resistance	[redacted]	🟩 [redacted]	[redacted]	🟩 [redacted]
Rebound (23°C)	[redacted]	🟩 [redacted]	[redacted]	🟥 [redacted]
Rebound (85°C)	[redacted]	🟩 [redacted]	[redacted]	🟥 [redacted]
Abrasion	[redacted]	🟥 [redacted]	[redacted]	🟥 [redacted]
Compression set				
70h/ 23°C	[redacted]	🟥 [redacted]	[redacted]	🟥 [redacted]
22h/ 70°C	[redacted]	🟥 [redacted]	[redacted]	🟩 [redacted]

Assessment of product requirements:

Table 6 summarises the assessment of Addolink® 1604 PU properties against the product requirements presented in Chapter 3.1.2.3.

Table 6. Assessment of product requirements (#A for all redactions in the table)

Property	**Addolink® 1604/TDI ether**	**Addolink® 1604/TDI ester**
Mechanical strength *Key requirement for all product types*	PU tensile strength is too low. This means the parts will fail (powder or crack) during use. **Conclusion: requirement not met for the three product types.**	The difference in PU tensile strengths is not as pronounced as for the ether system. The values are however still too low. **Conclusion: requirement not met for the three product types.**
Dynamic load bearing *Key requirement for heavy duty rollers and spring blocks*	The dynamic load bearing capacity of Addolink® 1604/TDI ether PUs are insufficient. It is [redacted] kg lower than TDI/MOCA PU, which corresponds to an approximately 41 % dynamic load bearing reduction. In practice, this means that the alternative parts will not be able to withstand the high loads used in this use and will deform permanently and break during use. **Conclusion: requirement not met for heavy-duty rollers and spring blocks.** **Not a key requirement for tensioner pads.**	The PU dynamic load bearing capacity is also a major issue with PUs made with the ester prepolymers as well. It is too low ([redacted] kg vs [redacted] kg for MOCA), which corresponds to an approximately 34 % reduction. **Conclusion: requirement not met for heavy-duty rollers and spring blocks.** **Not a key requirement for tensioner pads.**
Deflective/compression behaviour *Key requirement for tensioner pads and spring blocks*	The PU deflective behaviour is comparable to TDI/MOCA PU. PU compression set being slightly worse with this alternative, it will deform more during use. **Conclusion: requirement met for all products**	The PU deflective behaviour is comparable to TDI/MOCA PU. PU rebound is higher with this alternative (the material is more bouncy). This is an issue for tensioner pads and spring blocks, which are supposed to have low bounce-back. The pipes, cables or monopiles should not bounce when placed on the tensioner pads or spring blocks (the PU parts should absorb the shock). **Conclusion: requirement met for all products.**
Fatigue *Key requirement for all product types*	Based on customer feedback, fatigue properties of this material are lower than MOCA PU. Parts will need to be replaced more often increasing the costs for the end user. LUC UK's clients will not accept to buy less durable products. **Conclusion: requirement not met for all products.**	Based on customer feedback, fatigue properties of this material are lower than MOCA PU. Parts will need to be replaced more often increases the costs for the end user. LUC UK's clients will not accept to buy less durable products. **Conclusion: requirement not met for all products.**

Property	**Addolink® 1604/TDI ether**	**Addolink® 1604/TDI ester**
Coefficient of Friction *Key requirement for heavy duty rollers (driven) and tensioner pads*	PU CoF is insufficient at higher contact pressures, which are typical in Use 2 sectors due to the high loads applied to the PU part. **Conclusion: requirement not met for tensioner pads and driven heavy duty rollers** **Not a key requirement for spring blocks and non-driven rollers**	PU CoF is insufficient at higher contact pressures, which are typical in Use 2 sectors due to the high loads applied to the PU part. **Conclusion: requirement not met for tensioner pads and driven heavy duty rollers.** **Not a key requirement for spring blocks and non-driven rollers**
Reliability *Key requirement for all product types*	The parts produced with Addolink® 1604 are not as reliable as their MOCA counterparts. Users will have to change parts more often, which results in more frequent downtimes at user facilities. Downtime results in delays, financial loss and wasted labour (pipes/cables/monopiles cannot be installed if something is broken). **Conclusion: requirement not met for all products.**	Same as Addolink® 1604/TDI ether. **Conclusion: requirement not met for all products.**
Pot-life[16] and adhesion *Key requirements for all product types except adhesion is not a key requirement for spring blocks.*	Pot-life is sufficient. Good adhesion can be achieved. **Conclusion: all products covered can be casted. Adhesion is good.**	

3.3.1.1.5. Economic feasibility of Addolink® 1604

Addolink® 1604 is significantly more expensive than MOCA. The price of Addolink® 1604 used to be #B [20-50] £/kg (approx. 7 times the price of MOCA) however, due to poor availability/unavailability the price has increased to #B [30-80] £/kg. The current price of MOCA is #B [1-10] £/kg thus, Addolink® 1604 is currently approximately 13 times more expensive than MOCA.

The reason behind the high cost of Addolink® 1604 is not only due to its poor availability/unavailability. It is also expensive to manufacture due to the multistep synthesis required for its production as well as the safety and environmental issues associated with the manufacturing process.

Switching to this alternative would have a large impact on the production process, leading to an increase in production costs. The reaction profile and curing cycle is totally different

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[16] Not a product requirement but it is a limiting factor for the casting of products. A short pot life will not give enough time to cast the product.

with Addolink® 1604 i.e. the parts need to be kept in the oven longer thus, the energy consumption will increase with this alternative.

In addition, new equipment (e.g. ovens to maintain production capacity, temperature controllers, filtration unit) will most likely be required in case of substitution with this alternative.

Table 7 presents a qualitative comparison of the PU production costs involving Addolink® 1604 and MOCA.

Table 7. Qualitative comparison of PU production costs (Addolink® 1604 vs MOCA)

Aspect	**Addolink® 1604 vs MOCA**
Raw material costs	Significantly higher (approx. 13 times higher than MOCA)
Energy costs	Higher (longer time required in the oven)
Personnel costs	No change expected, since Addolink 1604's reaction profile and processing behaviour is the closest to that of MOCA. #C [redacted]
Scrap rate	Same as MOCA.

LUC UK has estimated the costs to implement an alternative for Use 2 products to amount to 490-546 k GBP, should a suitable alternative be found. For additional information, please see the substitution costs section and Table 64 in Chapter 4.1.3.1 of the AoA-SEA report of Use 1 of this application.

It would be impossible for LUC UK to absorb such a high material cost. LUC UK cannot increase the price of its products as they have to compete with the non-UK MOCA moulders who can still continue to place MOCA-cured PU products on the UK market. LUC UK's customers will simply not buy the alternative products at a higher price if they can continue to buy the cheaper MOCA-cured PU products.

In addition to having higher production costs, the PU products cured with this alternative do not have the high-performance and high reliability needed for this sector. Supply of products with inferior performance and reliability will result in damage to the LUC Group brand and customers will switch to non-UK MOCA moulders.

3.3.1.1.6. Suitability of Addolink® 1604 for the applicant in general

Addolink® 1604 cannot be considered a suitable alternative to MOCA in Use 2 products as summarised in Table 8.

Table 8. Limitations of the alternative

- PU dynamic load bearing capacity is significantly lower with Addolink® 1604 (parts will break during end-use). The loads are extremely high in the offshore energy and renewable sectors making dynamic load bearing capacity a key property
- PU tensile strength is too low (parts will break during end-use)
- PU rebound (TDI ester system only) and compression set are different leading to a different material behaviour in end-use
- PU CoF is too low for tensioner pads and driven heavy duty rollers (safety risk)
- PU fatigue and reliability properties are lower (customers will need to change/recover PU parts more often)
- Addolink® 1604 is currently poorly available
- The significantly higher raw material costs and higher energy costs increases the total production costs significantly

Technical feasibility	Economic feasibility	Availability	Safety considerations
🟥	🟥	🟥	🟩

3.3.1.2. Diamine blends

3.3.1.2.1. General description of diamine blends

For a general description of two most promising diamine blends for Use 2 – Blend 1 and Blend 2 – please see Chapter 3.3.1.1.1 in the AoA-SEA report of Use 1 of this application.

In addition, since the submission of the authorisation application under EU REACH, LUC Group has tested one further alternative, Blend 5 (#A [redacted]), which is a new commercially available curative blend consisting of #A [redacted]. Additional substance identity information is provided in Table 9 and Table 10. The aromatic diamines #A [redacted]

Table 9. Substance identity and classification #A [redacted] (#A for all redactions in the table)

	[redacted]
IUPAC name	[redacted]
Trade name	[redacted]
Structural formula	[redacted]
Molecular formula	[redacted]
Molecular weight	[redacted]
EC number	[redacted]
CAS number	[redacted]
Hazard information	[redacted]
Physical properties	[redacted]

Table 10. Substance identity and classification #A [redacted]
(#A for all redactions in the table)

	[redacted]
IUPAC name	[redacted]
Structural formula	[redacted]
Molecular formula	[redacted]
Molecular weight	[redacted]
EC number	[redacted]
CAS number	[redacted]
Hazard information	[redacted]
Physical properties	[redacted]

3.3.1.2.2. Availability of diamine blends

For a description of the availability of #A [redacted] used in Blend 1 and Blend 2, please see Chapter 3.3.1.1.2 in the AoA-SEA report of Use 1 of this application. Blend 5 is a commercially available blend (#A [redacted]).

3.3.1.2.3. Safety considerations related to using diamine blends

For a description of the safety considerations related to using diamine blends, please see Chapter 3.3.1.1.3 in the AoA-SEA report of Use 1 of this application.

#A [redacted] is also less hazardous to human health than MOCA.

3.3.1.2.4. Technical feasibility of diamine blends

Due to its high reactivity, [redacted] is only useable in the polyether/TDI prepolymer system, when blended with curing agents having lower reactivity. The reactivity of Blend 5 is also poor in ester-TDI (ca. [redacted] min in [redacted]°A system) and the primary requirement is therefore not met.

Ether prepolymer system:

Based on LUC Group's tests, the processability of the diamine blends was fair in the ether prepolymer system. Their pot-lives were shorter than MOCA (approximately [redacted] min for Blend 1, [redacted] min for Blend 2 and [redacted] min for Blend 5 compared to approximately [redacted] min for MOCA). As a result, the heavy duty rollers cannot be casted with Blend 1 nor Blend 5. The pot-life is however sufficient to cast tensioner pads and spring blocks.

LUC Group conducted tests to compare the technical properties of products prepared with Blend 1, Blend 2 and Blend 5 to those of TDI/MOCA. The results are presented Table 11.

Table 11. Test results of the comparative study between PUS made with MOCA/TDI ether prepolymer and three different diamine blends with a TDI ether prepolymer (#A for all redactions in the table)

			MOCA/TDI ether –[redacted]°A			TDI ether –[redacted]°A		
Property	Standard	Unit	Min. value	Nominal	Max. value	Blend 1	Blend 2	Blend 5
Hardness (23°C)	ISO 48-4	°A	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Hardness (85°C)	ISO 48-4	°A	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Tensile strength	ISO 37[1]	Mpa	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Elongation at break	ISO 37[1]	%	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Tear resistance	ISO 34-1 method B, procedure b	kN/m	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Rebound (23°C)	ISO 4662	%	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Rebound (85°C)	ISO 4662	%	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Abrasion	ISO 4649 method B	mm³	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Compression set								
70h/ 23°C	ISO 815-1	%	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
22h/ 70°C	ISO 815-1	%	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

[1] LUC Group uses 200 mm/min instead of 500 mm/min as test speed on the tensile tester.

As can be seen from the table above, the tensile strength of PUs made with Blend 1 and Blend 2 are worse than PUs made with MOCA. This is also demonstrated by the stress-strain curves (Figure 27). A lower amount of force (y-axis) was required to break the polyurethane pieces cured with Blend 1 and Blend 2 in comparison to MOCA cured PU. In terms of deflective behaviour, Blend 2 PU matches the deflective behaviour of TDI/MOCA PU the best as depicted by the shape of the curves.

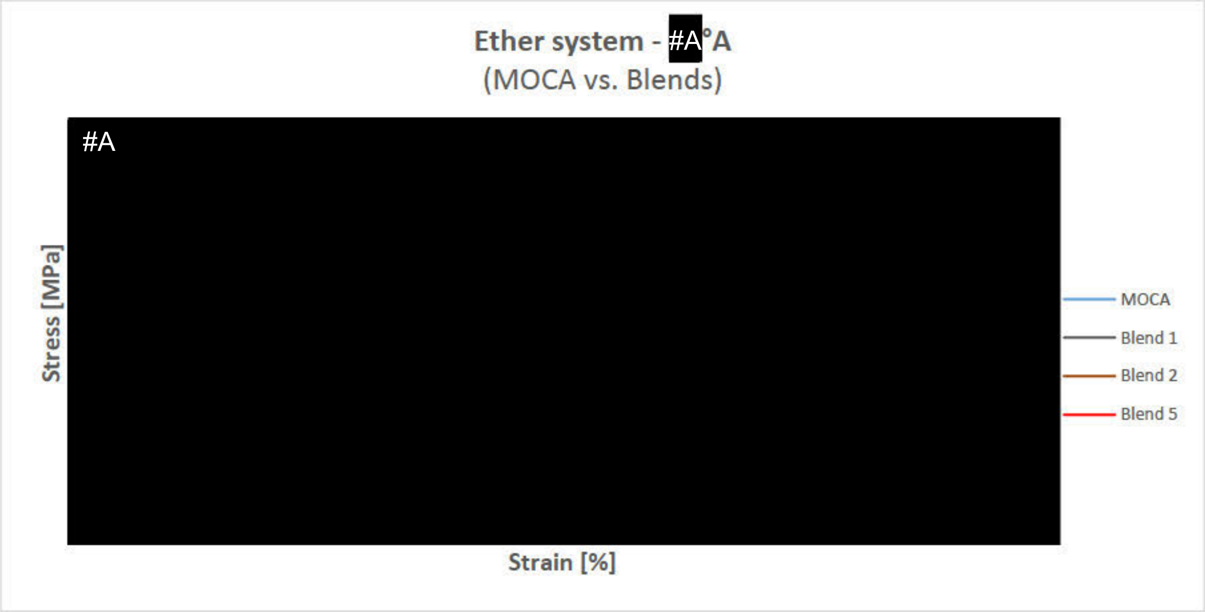

Figure 27. Stress-strain curves plotted from the results of ISO 37 test

The results of the dynamic behaviour test are presented in Figure 28. As can be seen from the results, the MOCA cured material can withstand higher loads than the alternative PU material. The alternative PU material starts building up heat and fails already under a load of [redacted] kg, which is [redacted] kg less than MOCA PU. Load bearing resistance is critical for Use 2 products due to the extreme loads the parts are subjected to. The dynamic behaviour measurements for Blend 5 are still in progress. Additional testing is ongoing at LUC Group's R&D department.

Figure 28. Test results showing the different dynamic behaviour of PU cured with Blend 1, Blend 2 and MOCA

The next 3 figures show the results of the CoF tests conducted by LUC Group. The CoF of PUs made with the blends tested were lower on the three counter materials especially at higher contact pressures. The CoF measurements for Blend 5 are still in progress. Additional testing is ongoing at LUC Group's R&D department.

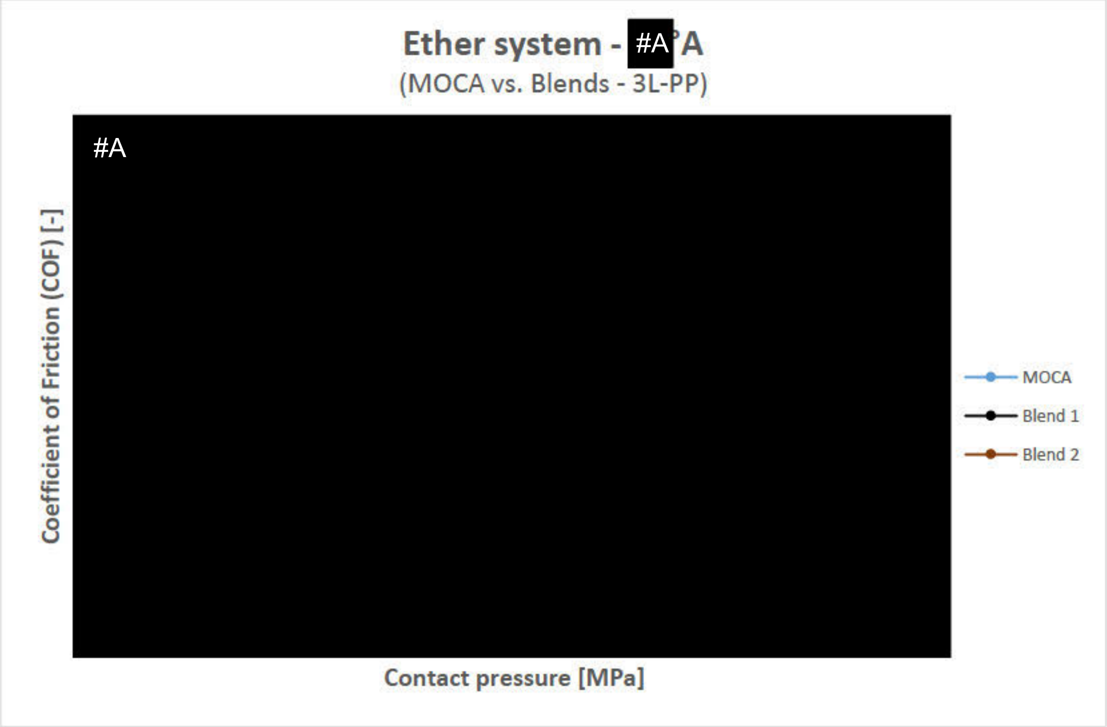

Figure 29. Results of the CoF test using 3-layer polypropylene

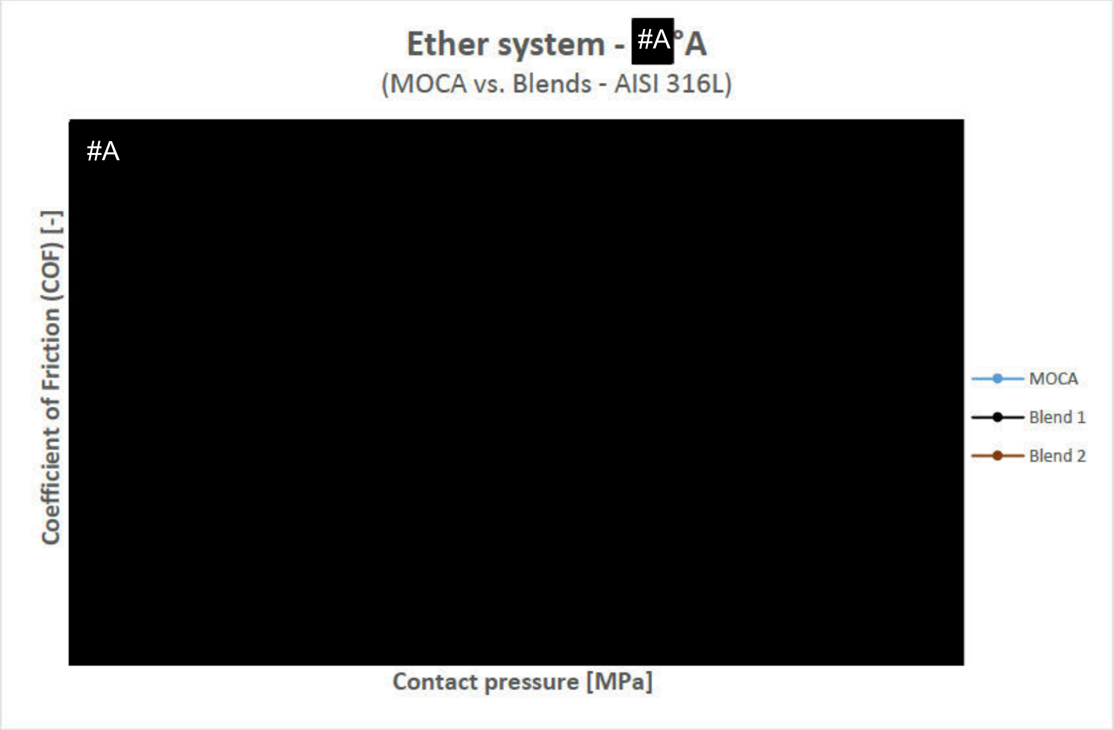

Figure 30. Results of the CoF test using stainless steel

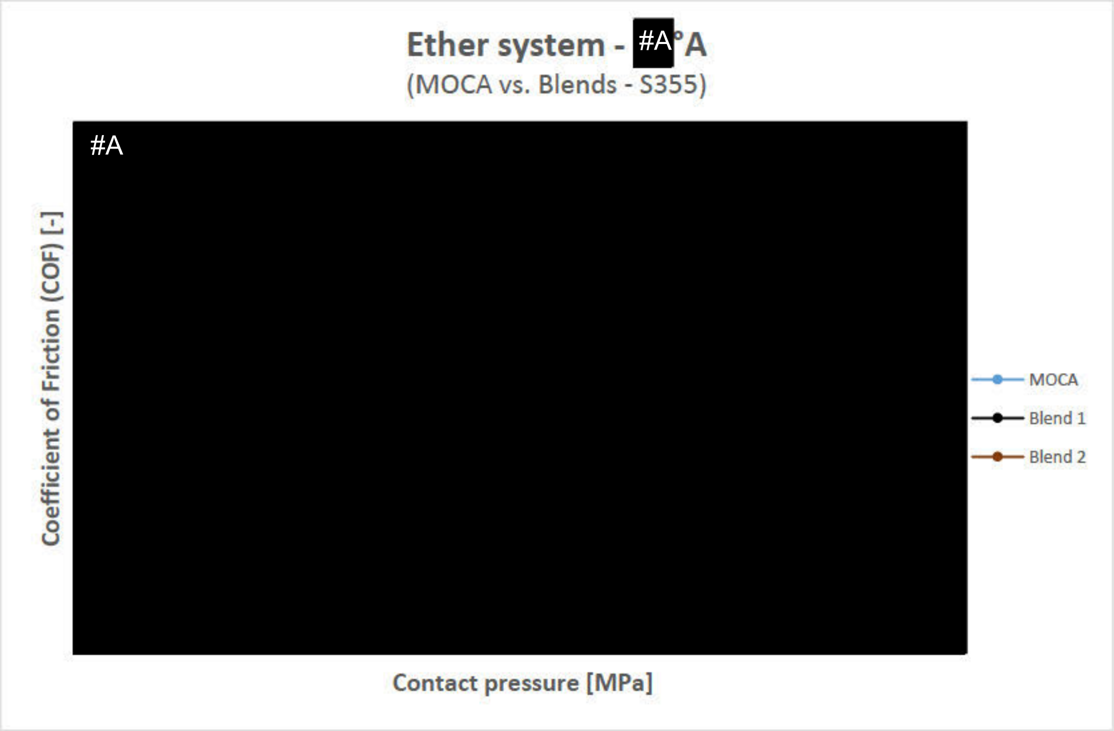

Figure 31. Results of the CoF test using steel

<u>Assessment of product requirements:</u>

Table 12 gives an assessment of the PU properties of the diamine blends against the product requirements presented in Chapter 3.1.2.3.

Table 12. Assessment of product requirement (#A for all redactions in the table)

Property	**Diamine blends/TDI ether**	
	Blend 1	**Blend 2**
Mechanical strength *Key requirement for all product types*	PU tensile strength is too low. The resulting PU products will be less sturdy and break during use. PU abrasion resistance is too low. The parts will have lower durability. **Conclusion: requirement not met for all products.**	Same as Blend 1. **Conclusion: requirement not met for all products.**
Dynamic load bearing *Key requirement for heavy duty rollers and spring blocks.*	Blend 1 PU has insufficient dynamic load bearing capacity. It is [redacted] kg lower than MOCA, which corresponds to an approximately 41 % load bearing reduction. In practice, this means that the alternative parts will not be able to withstand the high loads used in this use and will deform permanently and fail (powdering or cracking) during use. **Conclusion: requirement not met for heavy duty rollers and spring blocks.** **Not a key requirement for tensioner pads.**	The dynamic load bearing capacity of Blend 2 is too low. **Conclusion: requirement not met for heavy duty rollers and spring blocks.** **Not a key requirement for tensioner pads.**
Deflective/compression behaviour *Key requirement for all product types*	The PU deformation behaviour is comparable to TDI/MOCA PU. PU Compression set being slightly worse with this alternative, the resulting PU products will deform more during use. This affects negatively the durability of the parts. PU rebound is lower with this alternative. **Conclusion: requirement met for all products.**	The deformation behaviour is comparable to TDI/MOCA PU. PU compression set is slightly worse than MOCA at room temperature. PU rebound is lower with this alternative. **Conclusion: requirement met for all products.**
Fatigue *Key requirement for all product types*	Based on preliminary wheel tests, the PU fatigue properties are lower than TDI/MOCA PU. It failed after fewer rotations. **Conclusion: requirement not met for all products.**	Same as for Blend 1. **Conclusion: requirement not met for all products.**

Property	**Diamine blends/TDI ether**	
	Blend 1	**Blend 2**
Coefficient of Friction *Key requirement for driven heavy duty rollers and tensioner pads*	PU CoF is too low, especially at higher contact pressures. **Conclusion: requirement not met for tensioner pads and driven heavy duty rollers.** **Not a key requirement for spring blocks and non-driven heavy duty rollers.**	PU CoF is too low, especially at higher contact pressures. **Conclusion: requirement not met for tensioner pads and driven heavy duty rollers.** **Not a key requirement for spring blocks and non-driven heavy duty rollers.**
Reliability *Key requirement for all product types*	The parts cured with Blend 1 have lower reliability than TDI/MOCA PU parts. **Conclusion: requirement not met for all products.**	The parts cured with Blend 2 have lower reliability than TDI/MOCA PU parts. **Conclusion: requirement not met for all products.**
Pot-life[17] and adhesion *Key requirement for all product types*	Pot-life is shorter than with TDI/MOCA. The pot-life is insufficient to cast heavy duty rollers. Issues with adhesion may arise with tensioner pads. **Conclusion: Heavy duty rollers can only be casted with Blend 2.** **Tensioner pads and spring blocks can be casted. When casted with Blend 1, there is a higher risk of delamination.**	

3.3.1.2.5. Economic feasibility of diamine blends

#B This makes the raw material costs for Blend 2 #B high. Blend 5 (#B £/kg) is also significantly more expensive than MOCA.

The transition to diamine blends would require investments to be made in production. New mixing heads will be needed for quicker mixing of the prepolymer and chain extender in the mixing chamber to have more time available for casting. In addition, other components will need to be changed such as pumps, heating system, valves and sealing.

Table 13 gives an overview of the change in costs due to the substitution of MOCA with diamine blends.

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[17] Not a product requirement but it is a limiting factor for the casting of products. A short pot life will not give enough time to cast the product.

Table 13. Qualitative assessment of the change in costs due to transition to diamine blends

Aspect	**Diamine blends vs MOCA**
Raw material costs	Significantly higher, especially for Blend 2
Energy costs	Same as MOCA.
Personnel costs	If implemented, training of personnel would be required as this type of blends are not in use at LUC UK. Personnel costs would therefore be momentarily higher after implementation and returning back to normal afterwards.
Scrap rate	2-10 times higher

LUC UK has estimated the costs to implement an alternative for Use 2 products to amount to 490-546 k GBP, should a suitable alternative be found. For additional information, please see the substitution costs section and Table 64 in Chapter 4.1.3.1 of the AoA-SEA report of Use 1 of this application.

It would be impossible for LUC UK to absorb such a high material cost. LUC UK cannot increase the price of its products as they have to compete with the non-UK MOCA moulders who can still continue to place TDI/MOCA-cured PU products on the UK market. LUC UK's customers will simply not buy the alternative products at a higher price if they can continue to buy the cheaper TDI/MOCA PU products.

In addition to having higher production costs, the PU products cured with this alternative do not have the high-performance and high reliability needed for this sector. Supply of products with inferior performance and reliability will result in damage to the LUC Group brand and customers will switch to non-UK MOCA moulders.

3.3.1.2.6. Suitability of diamine blends for the applicant in general

Blend 1 and 2 cannot be considered as suitable alternatives to MOCA in Use 2 products as summarised in Table 14. Blend 5 cannot currently be considered as a suitable alternative to MOCA in Use 2 products as the technical feasibility is still under assessment. Further testing is ongoing at LUC Group's R&D department.

Table 14. Limitations of the alternative

<table>
<tr><td colspan="4">– PU tensile strength is too low (parts will break during use)
– PU dynamic load bearing is too low (parts will break during use)
– Pot-life is lower than MOCA. Heavy duty rollers cannot be casted with Blend 1 nor with Blend 5
– PU CoF is too low for tensioner pads and driven heavy duty rollers (safety risk)
– PU fatigue and reliability properties are lower (customers will need to change/recover PU parts more often)
– Significantly higher raw material costs
– #A [redacted] Blend 5 is commercially available.</td></tr>
<tr><td>Technical feasibility</td><td>Economic feasibility</td><td>Availability</td><td>Safety considerations</td></tr>
<tr><td>🟥</td><td>🟥</td><td>🟨</td><td>🟩</td></tr>
</table>

3.3.2. NDI systems: NDI/BDO

3.3.2.1. General description of NDI/BDO

For a general description of NDI/BDO, please see Chapter 3.3.3.1 in the AoA-SEA report of Use 1 of this application.

3.3.2.2. Availability of NDI/BDO

For a description of the availability of NDI/BDO, please see Chapter 3.3.3.2 in the AoA-SEA report of Use 1 of this application.

3.3.2.3. Safety considerations related to using NDI/BDO

For a description of the safety considerations related to using NDI/BDO, please see Chapter 3.3.3.3 in the AoA-SEA report of Use 1 of this application.

3.3.2.4. Technical feasibility of NDI/BDO

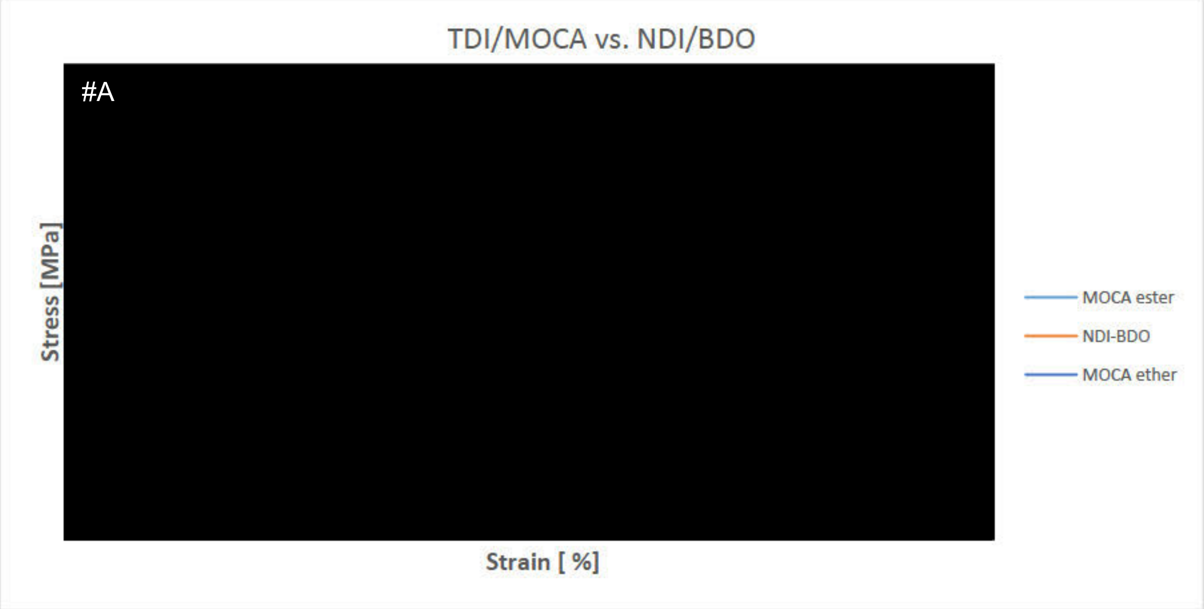
The processing of NDI prepolymer systems differ significantly from the TDI-based system currently in use at LUC UK. NDI systems have a much higher reactivity (shorter pot-life) making it impossible to cast the higher volume products (i.e. heavy duty rollers) covered by this use. The curing process takes significantly longer with NDI prepolymers (3 weeks vs 1 day for TDI/MOCA), which will result in higher energy consumption and will require additional oven space.

The results of the tests conducted by LUC Group are presented in Table 15. In addition, the PU made with the alternative system had a much higher rebound (i.e. more bouncy) than TDI/MOCA PU.

Table 15. Test results of the comparative study between PUs made with TDI/MOCA and NDI/BDO with an ester prepolymer (#A for all redactions in the table)

			MOCA/TDI ester - [redacted]°A			Ester - [redacted]°A
Property	Standard	Unit	Min. value	Nominal	Max. value	NDI/BDO
Hardness (23°C)	ISO 48-4	°A	[redacted]	[redacted]	[redacted]	[redacted]
Hardness (85°C)	ISO 48-4	°A	[redacted]	[redacted]	[redacted]	[redacted]
Tensile strength	ISO 37[1]	MPa	[redacted]	[redacted]	[redacted]	[redacted]
Elongation at break	ISO 37[1]	%	[redacted]	[redacted]	[redacted]	[redacted]
Tear resistance	ISO 34-1 method B, procedure b	kN/m	[redacted]	[redacted]	[redacted]	[redacted]
Rebound (23°C)	ISO 4662	%	[redacted]	[redacted]	[redacted]	[redacted]
Rebound (85°C)	ISO 4662	%	[redacted]	[redacted]	[redacted]	[redacted]
Abrasion	ISO 4649 method B	mm^3	[redacted]	[redacted]	[redacted]	[redacted]
Compression set			[redacted]	[redacted]	[redacted]	[redacted]
70h/ 23°C	ISO 815-1	%	[redacted]	[redacted]	[redacted]	[redacted]
22h/ 70°C	ISO 815-1	%	[redacted]	[redacted]	[redacted]	[redacted]

The stress-strain curves of the tested materials are presented in Figure 32. As can be seen, TDI/MOCA PU has a completely different deformation profile than the PU made with the alternative system when exposed to tension. Under lower load, NDI/BDO PU stretches less than TDI/MOCA PU while it is the contrary under higher loads. The difference in PU deformation behaviour is an issue and can cause major safety issues.



[redacted]

Figure 32. Stress-strain curves plotted from the results of ISO 37 test

The results of the dynamic behaviour test are presented in Figure 33. NDI/BDO PU surpasses TDI/MOCA PU in terms of load bearing capacities.

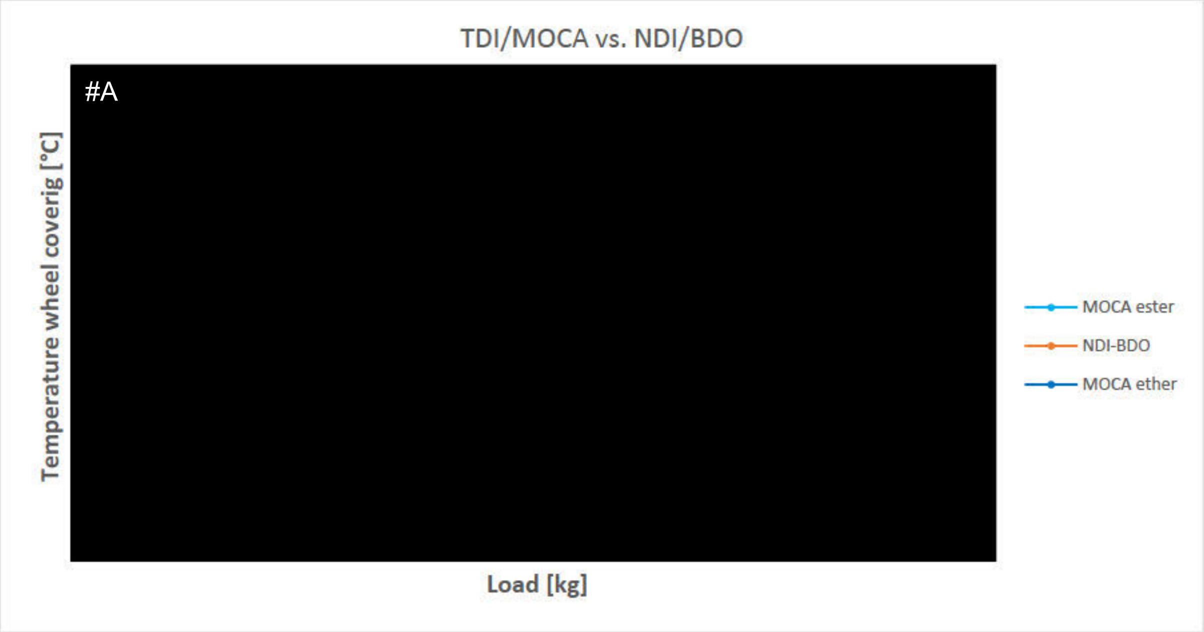


Figure 33. Test results showing the different dynamic behaviour of NDI/BDO PU and TDI/MOCA PU

The results of the CoF tests conducted on NDI/BDO PU are presented in the next three figures. As it can be seen, NDI/BDO PU has a significantly lower CoF compared to TDI/MOCA PU. A reduction of approximately [redacted] in CoF was observed in comparison to MOCA/TDI ester PU.

Figure 34. Results of the CoF test using 3-layer polypropylene

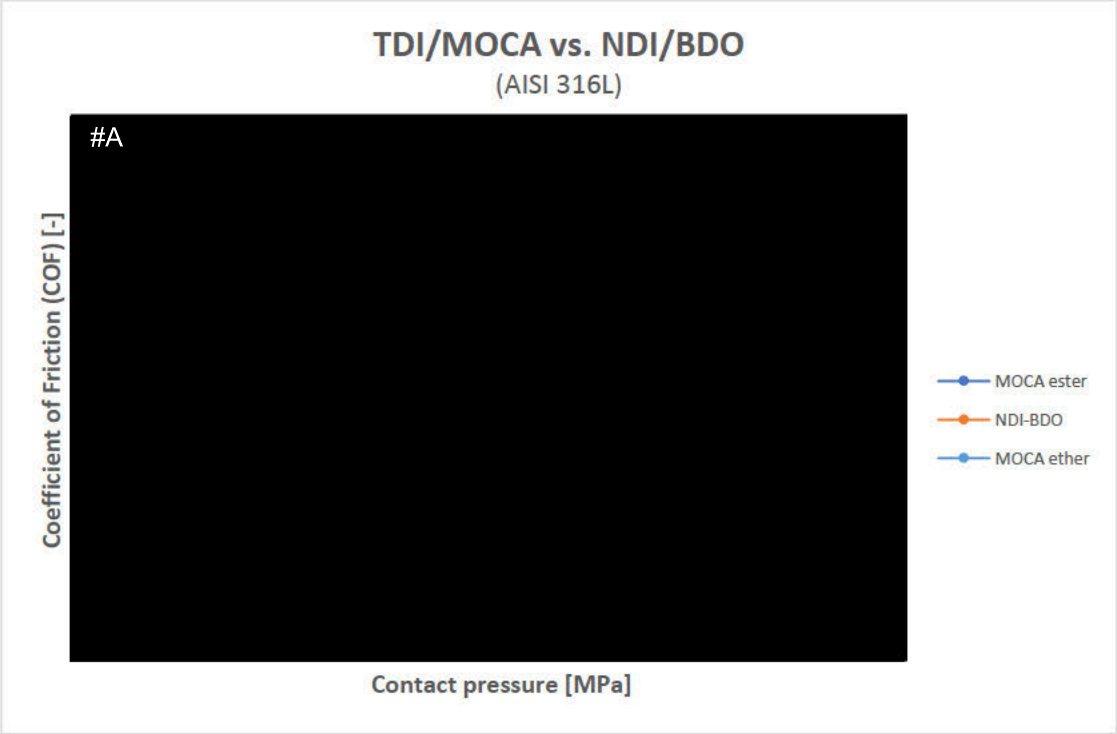


Figure 35. Results of the CoF test using stainless steel

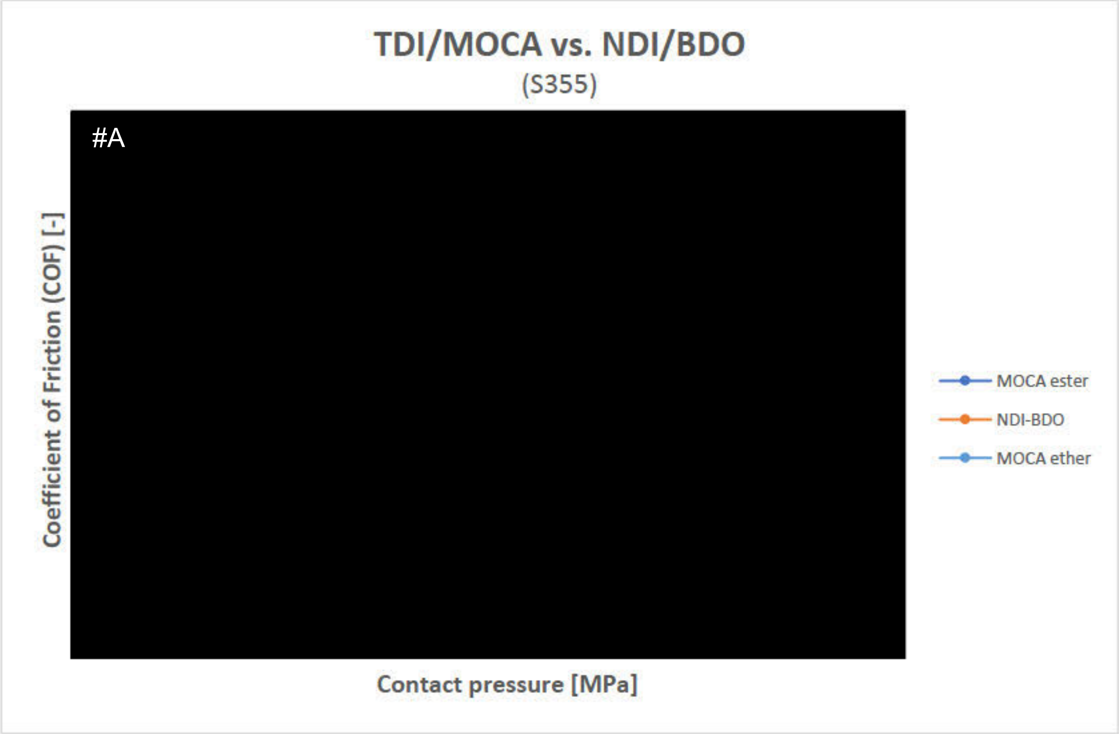


Figure 36. Results of the CoF test using steel

Assessment of product requirements:

Table 16 gives an assessment of the properties of NDI/BDO systems against the product requirements presented in Chapter 3.1.2.3.

Table 16. Assessment of product requirements

Property	**BDO/NDI ester**
Mechanical strength *Key requirement for all product types*	PU mechanical strength is good. **Conclusion: requirement met for all products.**
Dynamic load bearing *Key requirement for heavy duty rollers and spring blocks*	PU dynamic load bearing is higher than the TDI/MOCA systems. **Conclusion: requirement met for heavy duty rollers and spring blocks.** **Not a key requirement for tensioner pads.**
Deflective/compression behaviour *Key requirement for all product types*	PU deflective/compression behaviour is completely different when compared to TDI/MOCA. As the applications concerned are characterised by strict safety requirements, the difference in deformation behaviour is an issue for Use 2 products. This can cause accidents involving material damage and fatalities. PU rebound is significantly higher with this alternative (the material is more bouncy). This is an issue for as the products are supposed to have low bounce-back. The pipes, cables or monopiles should not bounce when placed on the PU parts (the PU parts should absorb the shock). **Conclusion: requirement not met for all products.**
Fatigue *Key requirement for all product types*	PU fatigue properties are excellent. **Conclusion: requirement met for all products.**
Coefficient of Friction *Key requirement for driven heavy duty rollers and tensioner pads*	The PU coefficient of friction is insufficient. This is an issue for tensioner pads and driven heavy duty rollers as it can lead to article slippage (e.g. pipe) causing major safety risks with high economic repercussions. **Conclusion: requirement not met for driven heavy duty rollers and tensioner pads.** **Not a key requirement for spring blocks and non-driven heavy duty rollers.**
Reliability *Key requirement for all product types*	The parts produced with NDI/BDO show higher reliability than their MOCA counterparts. **Conclusion: requirement met for all products.**
Pot-life[18] and adhesion *Key requirement for all product types except adhesion is not a key requirement for spring blocks.*	Pot-life of NDI/BDO is lower than MOCA. The heavy duty rollers covered by this use cannot be casted due to their larger size. In addition, the shorter pot-life is an issue for spring blocks requiring higher hardness's leading to higher risk for defects in PU. For tensioner pads, there is a higher risk of poor adhesion with this alternative. **Conclusion: Heavy duty rollers cannot be casted.** **Tensioner pads and spring blocks can be casted. There is however a higher risk for defects in the PU and higher risk of delamination.**

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[18] Not a product requirement but it is a limiting factor for the casting of products. A short pot life will not give enough time to cast the product.

3.3.2.5. Economic feasibility of NDI/BDO

As the polyurethane is manufactured with an excess of prepolymer in comparison to the chain extender, the price of the prepolymer will have a much larger influence on the raw material costs than the chain extender because it is used in higher quantities. NDI prepolymers are more expensive (increase of a factor of 3) than the LF-TDI prepolymers in use at LUC UK. Although BDO is less expensive than MOCA, the higher price of the prepolymer still leads to an overall higher price of raw materials.

The longer curing time associated with NDI/BDO result in higher energy costs (as high as an increase of a factor of 10). In addition, additional oven space will be needed, which is an issue as not all LUC Group facilities, including LUC UK's site, have the space to accommodate additional ovens. This would require building an extension to the facilities. Based on LUC Group's estimates, an extension would cost approximately 1.8 M GBP per facility.

Table 17 gives an overview of the change in costs due to the transition to NDI/BDO.

Table 17. Qualitative assessment of the change in costs due to the substitution of TDI/MOCA with NDI/BDO

Aspect	NDI/BDO vs TDI/MOCA
Raw material costs	Significantly higher
Energy costs	Significantly higher (10 times higher than with TDI/MOCA)
Personnel costs	No change expected. LUC UK's personnel will not require additional training to use NDI/BDO. The substance is in use at LUC UK.
Scrap rate	Not applicable

LUC UK has estimated the costs to implement an alternative for Use 2 products to amount to 490-546 k GBP, should a suitable alternative be found. For additional information, please see the substitution costs section and Table 64 in Chapter 4.1.3.1 of the AoA-SEA report of Use 1 of this application.

It would be impossible for LUC UK to absorb such a high material cost. LUC UK cannot increase the price of its products as they have to compete with the non-UK MOCA moulders who can still continue to place TDI/MOCA PU products on the UK market. LUC UK's customers will simply not buy the alternative products at a higher price if they can continue to buy the cheaper TDI/MOCA PU- products.

In addition to having higher production costs, the PU products cured with this alternative do not have the high-performance and high reliability needed for this sector. Supply of products with inferior performance and reliability will result in damage to the LUC Group's brand and customers will switch to non-UK MOCA moulders.

3.3.2.6. Suitability of NDI/BDO for the applicant in general

The NDI/BDO system cannot be considered a suitable alternative to the TDI/MOCA system in Use 2 products as summarised in Table 18.

Table 18. Limitations of the alternative

<table>
<tr><td colspan="4">– PU coefficient of Friction is too low for tensioner pads and driven heavy-duty rollers (safety risk)
– PU deflective behaviour is completely different than TDI/MOCA, which is an issue for all products (safety risk)
– The pot-life of this alternative is so short that the heavy-duty rollers cannot be casted. There is also a higher risk for defects in PU and delamination for spring blocks and tensioner pads
– Significantly longer curing time with this alternative (3 weeks vs 1 day for TDI/MOCA)
– The higher raw material costs (NDI) and the significantly higher energy costs increases significantly the total production costs
– NDI availability is currently poor</td></tr>
<tr><td>Technical feasibility</td><td>Economic feasibility</td><td>Availability</td><td>Safety considerations</td></tr>
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</table>

3.3.3. PPDI systems

In this chapter, we present the test results for PPDI/BDO and PPDI/HQEE.

3.3.3.1. PPDI/BDO

3.3.3.1.1. General description of PPDI/BDO

For a general description of PPDI/BDO please see Chapter 3.3.4.1.1 in the AoA-SEA report of Use 1 of this application.

3.3.3.1.2. Availability of PPDI/BDO

For a description of the availability of PPDI/BDO please see Chapter 3.3.4.1.2 in the AoA-SEA report of Use 1 of this application.

3.3.3.1.3. Safety considerations related to using PPDI/BDO

For a description of the safety considerations related to using PPDI/BDO please see Chapter 3.3.4.1.3 in the AoA-SEA report of Use 1 of this application.

3.3.3.1.4. Technical feasibility of PPDI/BDO

The results of the tests conducted by LUC Group are presented in Table 19. PU tensile strength is out of specifications and the rebound resilience of the PU made with the alternative system is significantly higher than TDI/MOCA PU meaning it will be more bouncy.

Table 19. Test results of the comparative study between TDI/MOCA and PPDI/BDO PUs

(#A for all redactions in the table)

			MOCA/TDI ester - [redacted]°A			Ester - [redacted]°A
Property	Standard	Unit	Min. value	Nominal	Max. value	PPDI/BDO
Hardness (23°C)	ISO 48-4	°A	[redacted]	[redacted]	[redacted]	[redacted]
Hardness (85°C)	ISO 48-4	°A	[redacted]	[redacted]	[redacted]	[redacted]
Tensile strength	ISO 37[1]	MPa	[redacted]	[redacted]	[redacted]	[redacted]
Elongation at break	ISO 37[1]	%	[redacted]	[redacted]	[redacted]	[redacted]
Tear resistance	ISO 34-1 method B, procedure b	kN/m	[redacted]	[redacted]	[redacted]	[redacted]
Rebound (23°C)	ISO 4662	%	[redacted]	[redacted]	[redacted]	[redacted]
Rebound (85°C)	ISO 4662	%	[redacted]	[redacted]	[redacted]	[redacted]
Abrasion	ISO 4649 method B	mm^3	[redacted]	[redacted]	[redacted]	[redacted]
Compression set						
70h/ 23°C	ISO 815-1	%	[redacted]	[redacted]	[redacted]	[redacted]
22h/ 70°C	ISO 815-1	%	[redacted]	[redacted]	[redacted]	[redacted]

[1] LUC Group uses 200 mm/min instead of 500 mm/min as test speed on the tensile tester.

The stress-strain curves of the tested materials are shown in Figure 37. The deflective behaviour of PPDI/BDO PU is completely different than TDI/MOCA PU. Under lower tension loads, PPDI/BDO PU stretches less the TDI/MOCA PU while it stretches significantly more under higher loads. This means that the alternative PU will have a completely different deflective behaviour during end-use.

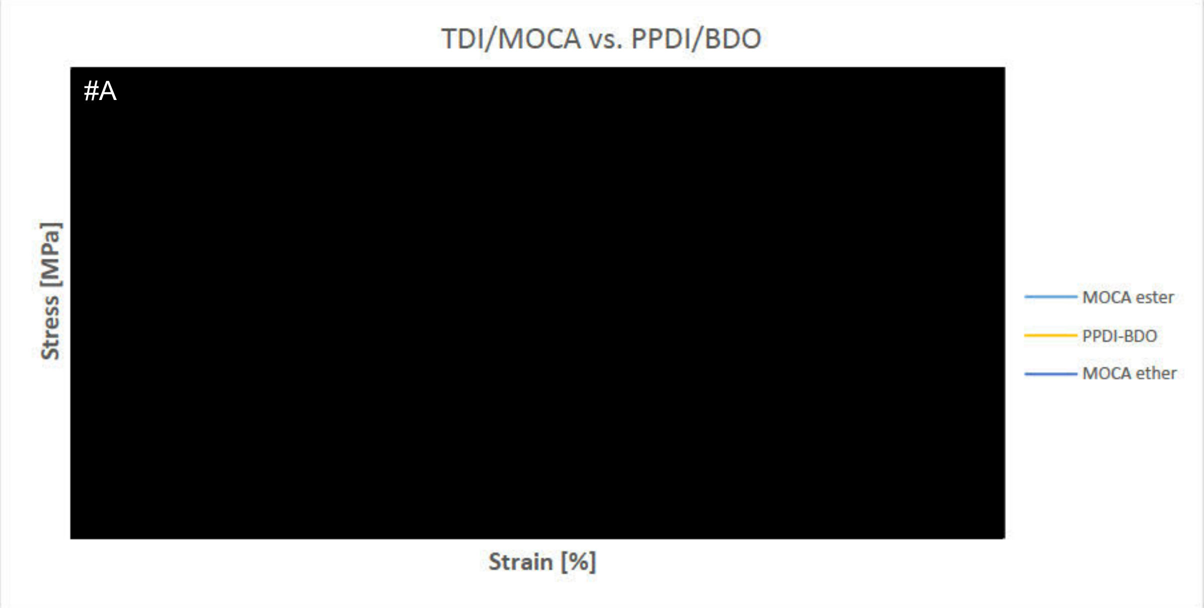
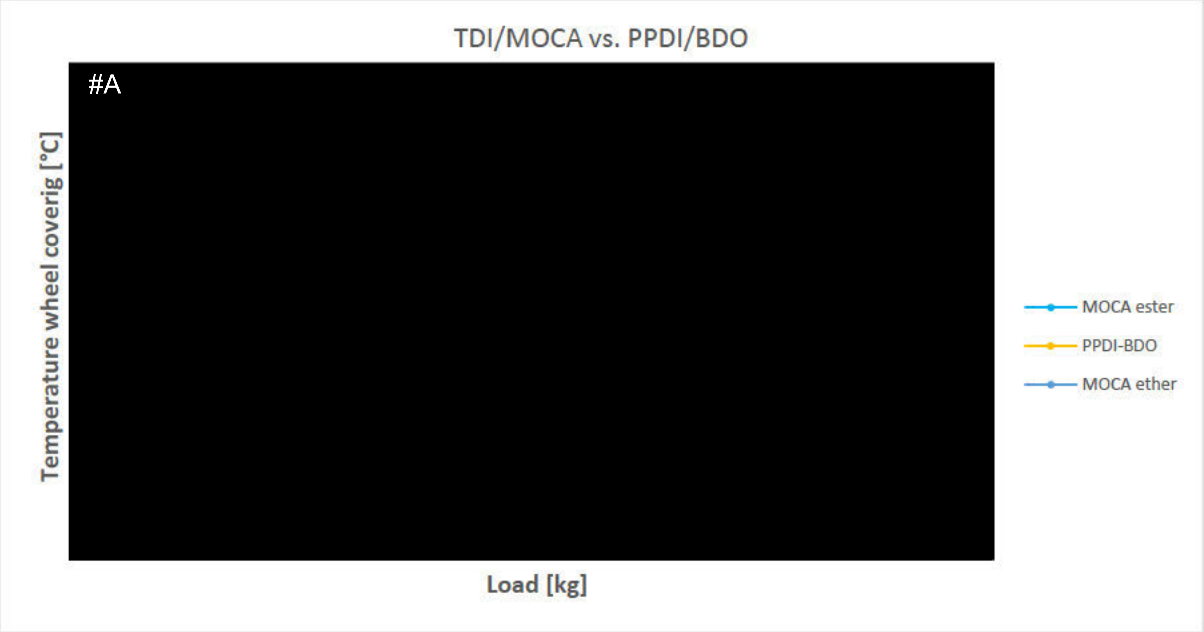

[redacted]

Figure 37. Stress-strain curves plotted from the results of ISO 37 test

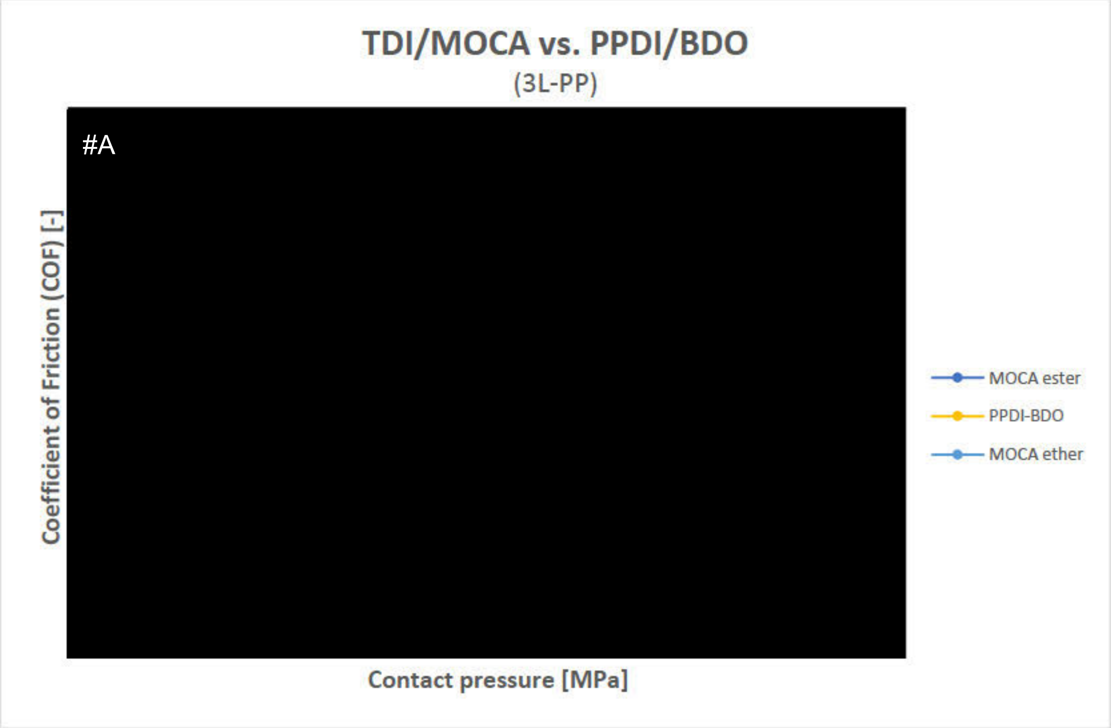
In terms of PU load bearing capacity, PPDI/BDO PU surpasses TDI/MOCA PU as can be seen from Figure 38.



[redacted]

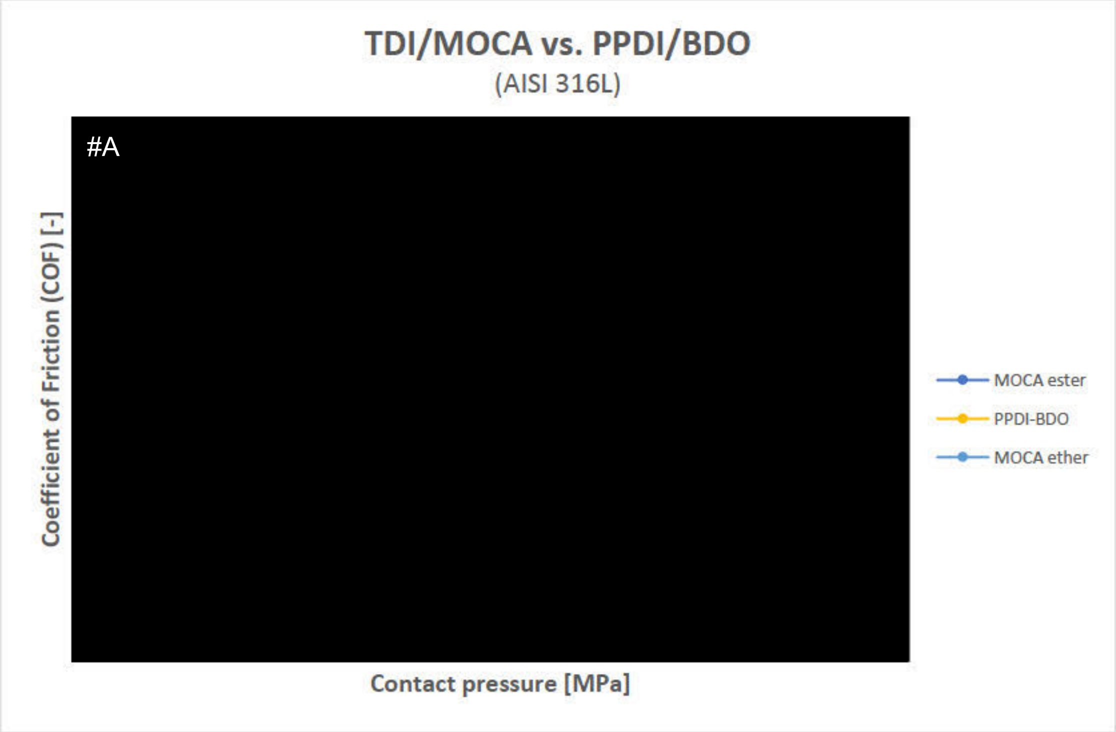
Figure 38. Test results showing the different dynamic behaviour of PPDI/BDO PU and TDI/MOCA PU

The results of the PU CoF tests conducted on PPDI/BDO PU are presented in the next three figures. PPDI/BDO PU has a significantly lower CoF than TDI/MOCA PU with all three counter materials (approx. [redacted] compared to MOCA/TDI ester system).



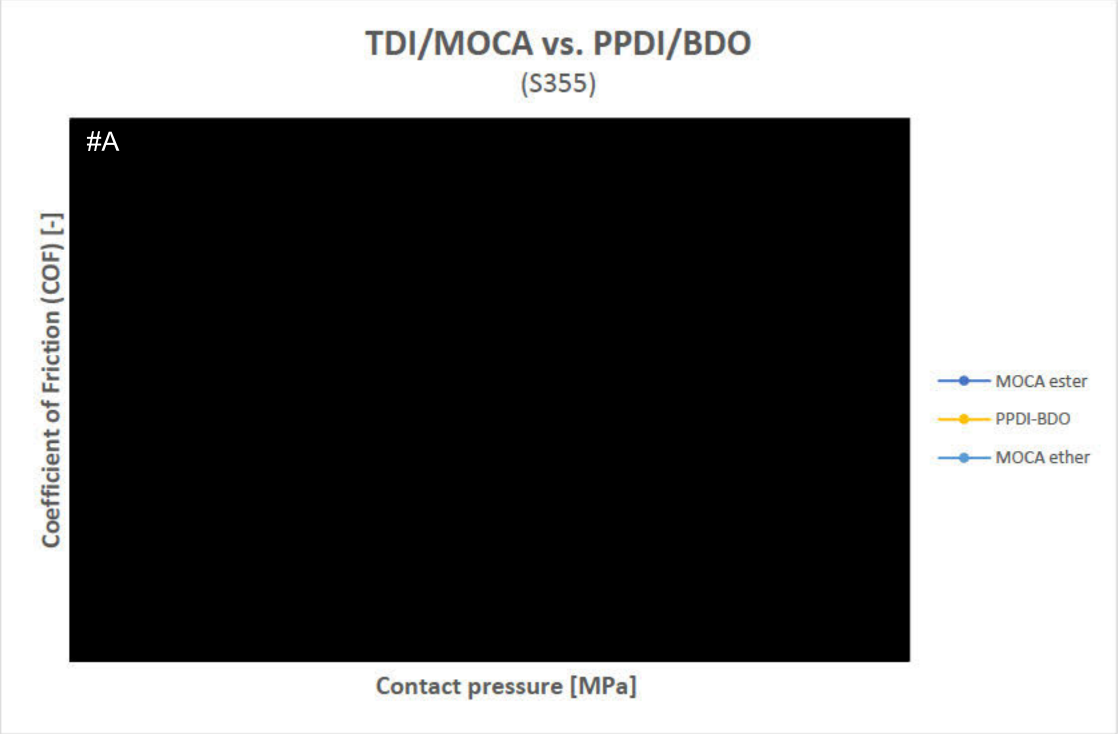
[redacted]

Figure 39. Results of the CoF test using 3-layer polypropylene



[redacted]

Figure 40. Results of the CoF test using stainless steel



[redacted]

Figure 41. Results of the CoF test using steel

Assessment of product requirements:

Table 20 gives an assessment of the PU properties of PPDI/BDO systems against the product requirements presented in Chapter 3.1.2.3.

Table 20. Assessment of product requirements

Property	**BDO/PPDI ester**
Mechanical strength *Key requirement for all product types*	PU Mechanical strength is good. **Conclusion: requirement met for all products.**
Dynamic load bearing *Key requirement for heavy duty rollers and spring blocks*	PU dynamic load bearing is higher than with the TDI/MOCA systems. **Conclusion: requirement met for heavy duty rollers and spring blocks.** **Not a key requirement for tensioner pads.**
Deflective/compression behaviour *Key requirement for all product types*	There are extreme differences in PU deflective/compression behaviour in comparison to TDI/MOCA. As the applications concerned are characterised by strict safety requirements, the difference in deformation behaviour is an issue for all products. This can cause accidents involving material damage and fatalities. PU rebound is significantly higher with this alternative (the material is more bouncy). This is an issue for Use 2 products, which are supposed to have low bounce-back. The pipes, cables or monopiles should not bounce when placed on the PU parts (the PU parts should absorb the shock). **Conclusion: requirement not met for all products.**
Fatigue *Key requirement for all product types*	PU with better fatigue properties than with TDI/MOCA PU. **Conclusion: requirement met for all products.**
Coefficient of Friction *Key requirement for driven heavy duty rollers and tensioner pads*	The PU coefficient of friction is insufficient. Tensioner pads and driven heavy duty rollers with too low CoF is a major safety risk with high economic repercussions. **Conclusion: requirement not met for tensioner pads and driven heavy duty rollers.** **Not a key requirement for spring blocks and non-driven heavy duty rollers.**
Reliability *Key requirement for all product types*	The parts produced with PPDI/BDO are more reliable than their MOCA counterparts. **Conclusion: requirement met for all products.**
Pot-life[19] and adhesion *Key requirement for all product types except adhesion is not a key requirement for spring blocks*	Pot-life of PPDI/BDO is shorter than MOCA. The heavy-duty rollers covered by this use cannot be casted due to their larger size. In addition, the shorter pot-life is an issue for spring blocks requiring higher hardness's leading to higher risk for defects in PU. For tensioner pads, there is a higher risk of poor adhesion with this alternative. **Conclusion: Heavy duty rollers cannot be casted.** **Tensioner pads and spring blocks can be casted. There is however a higher risk for defects in the PU and higher risk of delamination.**

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[19] Not a product requirement but it is a limiting factor for the casting of products. A short pot life will not give enough time to cast the product.

3.3.3.1.5. Economic feasibility of PPDI/BDO

PPDI is more expensive than TDI. Although BDO is less expensive than MOCA, the higher price of the prepolymer still leads to an overall higher price of raw materials.

The longer curing time associated with PPDI/BDO result in higher energy costs (as high as an increase of a factor of 10). In addition, additional oven space will be needed, which is an issue as not all LUC Group facilities, including LUC UK's site, have the space to accommodate additional ovens. This would require building an extension to the existing facilities. Based on LUC UK's estimates, an extension would cost approximately 1.8 M GBP per facility.

Table 21 gives an overview of the change in costs due to the transition to PPDI/BDO.

Table 21. Qualitative assessment of the change in costs due to the substitution of TDI/MOCA with PPDI/BDO

Aspect	**PPDI/BDO vs TDI/MOCA**
Raw material costs	Higher
Energy costs	Significantly higher (10 times higher than with TDI/MOCA)
Personnel costs	No change expected. LUC UK's personnel will not require additional training to use PPDI/BDO.
Scrap rate	Not applicable

LUC UK has estimated the costs to implement an alternative for Use 2 products to amount to 490-546 k GBP, should a suitable alternative be found. For additional information, please see the substitution costs section and Table 64 in Chapter 4.1.3.1 of the AoA-SEA report of Use 1 of this application.

It would be impossible for LUC UK to absorb such a high material cost. LUC UK cannot increase the price of its products as they have to compete with the non-UK MOCA moulders who can still continue to place TDI/MOCA PU products on the UK market. LUC UK's customers will simply not buy the alternative products at a higher price if they can continue to buy the cheaper TDI/MOCA PU products.

3.3.3.1.6. Suitability of PPDI/BDO for the applicant in general

PPDI/BDO cannot be considered a suitable alternative to MOCA in Use 2 products as summarised in Table 22.

Table 22. Limitations of the alternative

<table>
<tr><td colspan="4">– PU CoF is too low for tensioner pads and driven heavy-duty rollers (safety risk)
– PU deflective behaviour is completely different than TDI/MOCA, which is an issue for all products (safety risk)
– Pot-life is so short that the heavy-duty rollers cannot be casted. There is a higher risk of PU defects and delamination for tensioner pads and spring blocks
– Longer curing times are needed with this alternative
– The higher raw material costs (PPDI) and the significantly higher energy costs increases significantly the total production costs</td></tr>
<tr><td>Technical feasibility</td><td>Economic feasibility</td><td>Availability</td><td>Safety considerations</td></tr>
<tr><td>🟥</td><td>🟥</td><td>🟩</td><td>🟩</td></tr>
</table>

3.3.3.2. PPDI/HQEE

3.3.3.2.1. General description of PPDI/HQEE

For a general description of PPDI/HQEE, please see Chapter 3.3.4.2.1 in the AoA-SEA report of Use 1 of this application.

3.3.3.2.2. Availability of PPDI/HQEE

For a description of the availability of PPDI/HQEE, please see Chapter 3.3.4.2.2 in the AoA-SEA report of Use 1 of this application.

3.3.3.2.3. Safety considerations related to using PPDI/HQEE

For a description of the safety considerations related to using PPDI/HQEE, please see Chapter 3.3.4.2.3 in the AoA-SEA report of Use 1 of this application.

3.3.3.2.4. Technical feasibility of PPDI/HQEE

The results of the test conducted by LUC Group on PPDI/HQEE and TDI/MOCA are presented in Table 23. PPPDI/HQEE has several technical properties out of specifications. Tear resistance is significantly lower with PPDI/HQEE thus, the resulting PU product will be more vulnerable to tears. The PU made with the alternative system has a much higher rebound resilience making it more bouncy. This is an unwanted property in tensioner pads and spring blocks (minimal bounce back is required). PU tensile strength is lower than with TDI/MOCA PU thus, the products might break during use.

Table 23. Test results of the comparative study between TDI/MOCA and PPDI/HQEE PUs

(#A for all redactions in the table)

			MOCA/TDI ester - [redacted]°A			Ester - [redacted]°A
Property	Standard	Unit	Min. value	Nominal	Max. value	PPDI/HQEE
Hardness (23°C)	ISO 48-4	°A	[redacted]	[redacted]	[redacted]	[redacted]
Hardness (85°C)	ISO 48-4	°A	[redacted]	[redacted]	[redacted]	[redacted]
Tensile strength	ISO 37[1]	MPa	[redacted]	[redacted]	[redacted]	[redacted]
Elongation at break	ISO 37[1]	%	[redacted]	[redacted]	[redacted]	[redacted]
Tear resistance	ISO 34-1 method B, procedure b	kN/m	[redacted]	[redacted]	[redacted]	[redacted]
Rebound (23°C)	ISO 4662	%	[redacted]	[redacted]	[redacted]	[redacted]
Rebound (85°C)	ISO 4662	%	[redacted]	[redacted]	[redacted]	[redacted]
Abrasion	ISO 4649 method B	mm³	[redacted]	[redacted]	[redacted]	[redacted]
Compression set			[redacted]	[redacted]	[redacted]	[redacted]
70h/ 23°C	ISO 815-1	%	[redacted]	[redacted]	[redacted]	[redacted]
22h/ 70°C	ISO 815-1	%	[redacted]	[redacted]	[redacted]	[redacted]

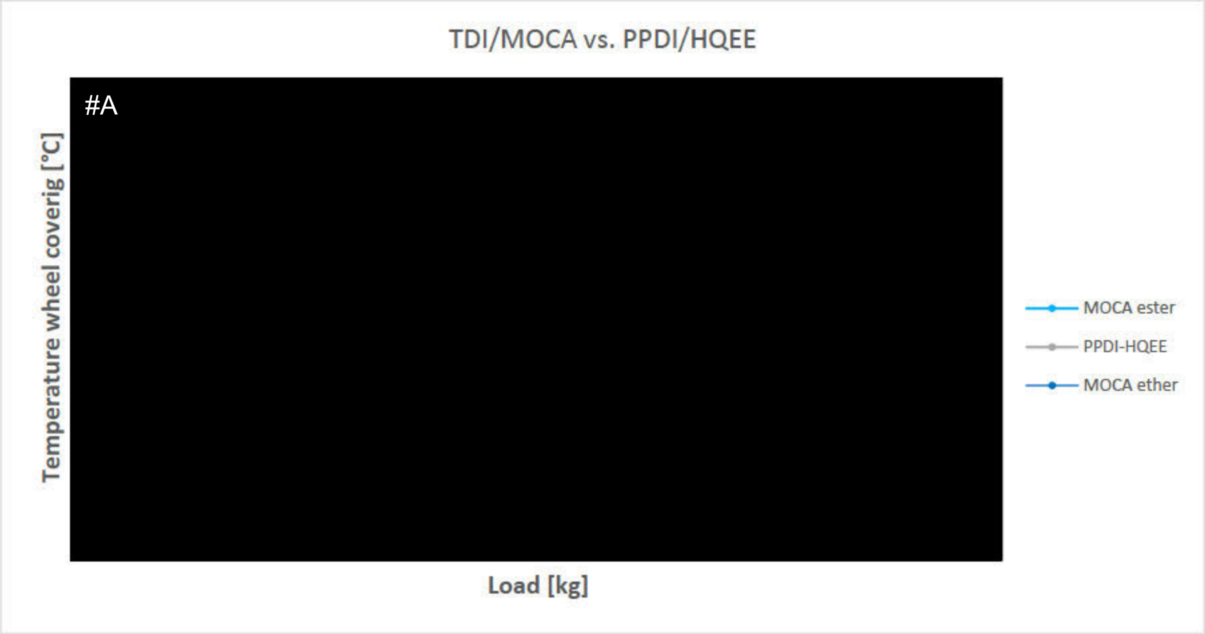
[1] LUC Group uses 200 mm/min instead of 500 mm/min as test speed on the tensile tester.

The stress-strain curves of the tested materials are presented in Figure 42. PPDI/HQEE PU has a totally different deflective behaviour than MOCA/TDI PU.

[redacted]

Figure 42. Stress-strain curves plotted from the results of ISO 37 test

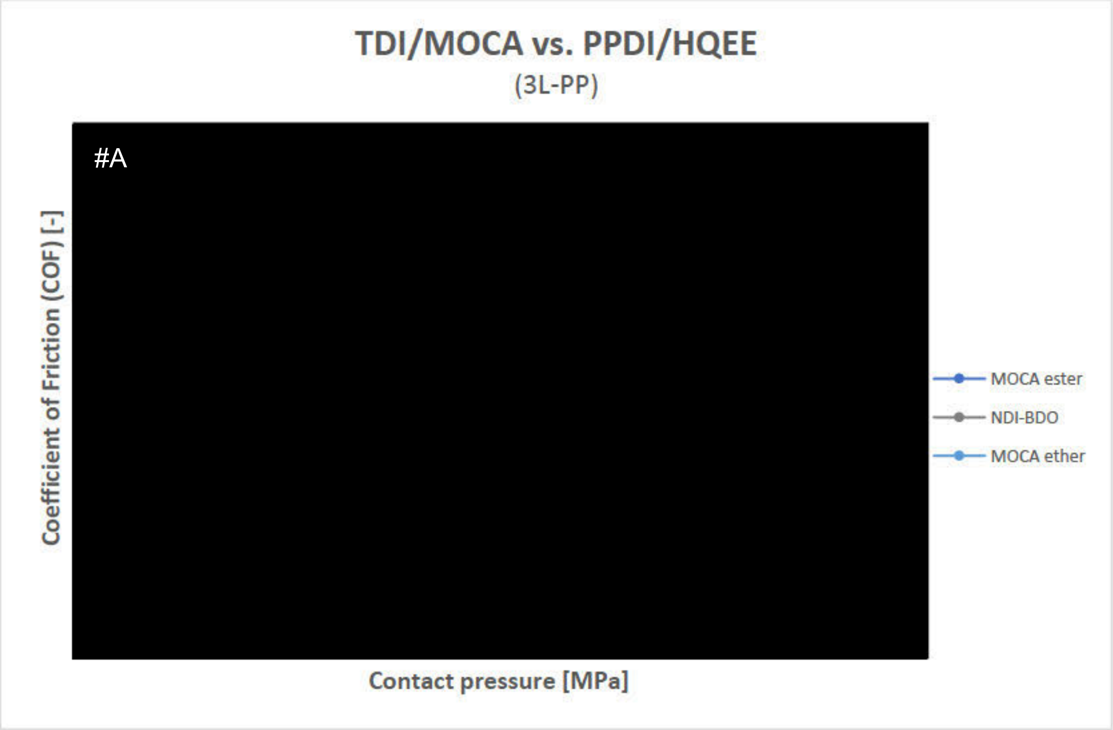
PPDI/HQEE has the same load bearing capacity as MOCA/TDI ester as it can be seen from Figure 43.



[redacted]

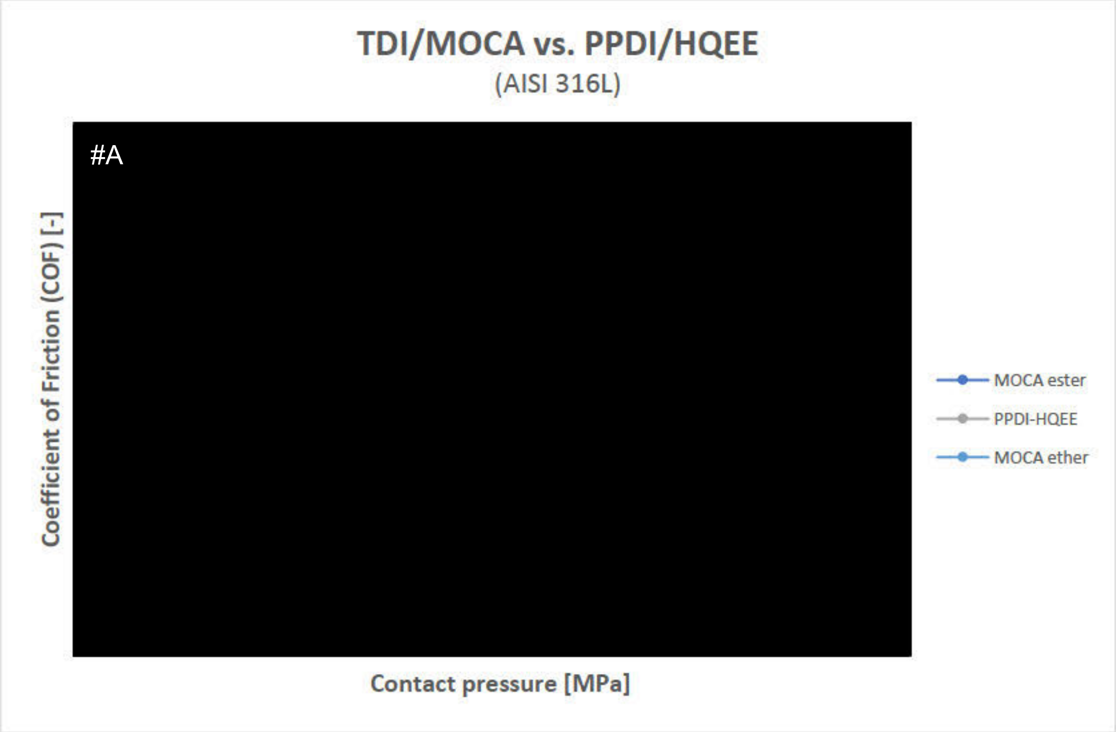
Figure 43. Test results showing the different dynamic behaviour of PPDI/HQEE PU and TDI/MOCA PU

The results of the PU CoF tests conducted by LUC Group are presented in the next three figures. PPDI/HQEE PU has a significantly lower CoF than TDI/MOCA PU.



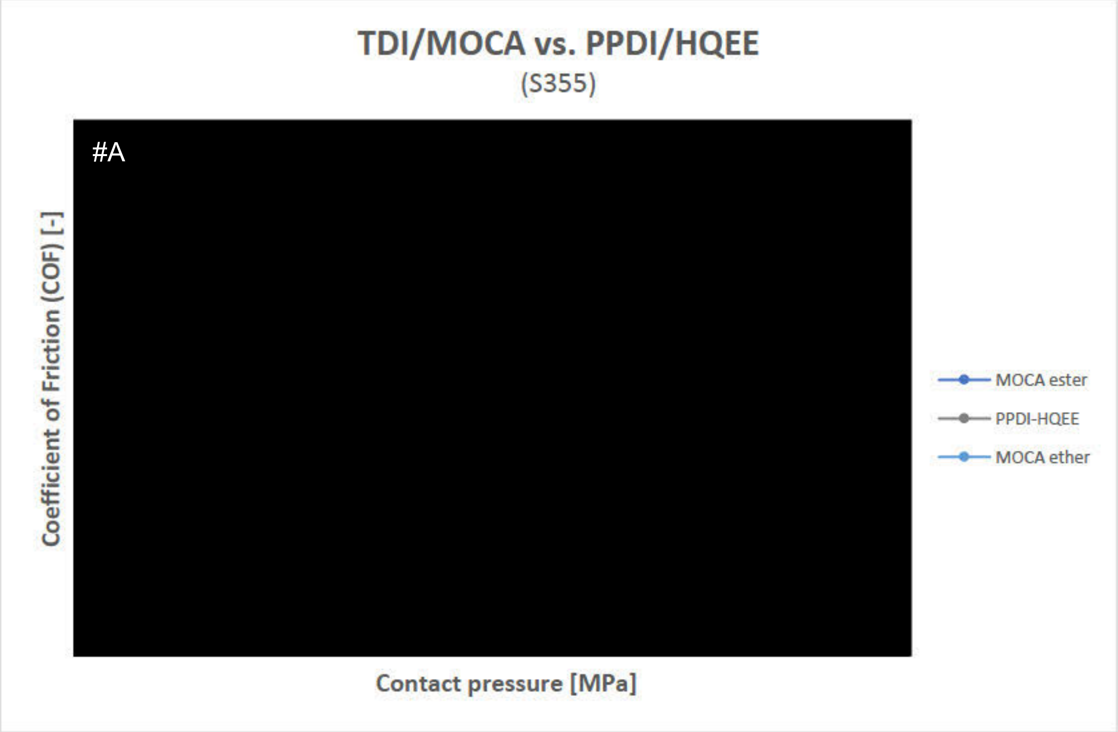
[redacted]

Figure 44. Results of the CoF test using 3-layer polypropylene



[redacted]

Figure 45. Results of the CoF test using stainless steel



[redacted]

Figure 46. Results of the CoF test using steel

Assessment of product requirements:

Table 24 gives an assessment of the properties of PPDI/HQEE systems against the product requirements presented in Chapter 3.1.2.3.

Table 24. Assessment of product requirements

Property	**HQEE/PPDI ester**
Mechanical strength *Key requirement for all product types*	PU tensile strength and tear resistance are too low. PPDI/HQEE PU will wear more easily and be less resistant under tension. **Conclusion: requirement not met for all products.**
Dynamic load bearing *Key requirement for heavy duty rollers and spring blocks*	HQEE/PPDI ester PU has the same load bearing capacity as MOCA/TDI ester PU. **Conclusion: requirement met for heavy duty rollers and spring blocks.** **Not a key requirement for tensioner pads.**
Deflective/compression behaviour *Key requirement for all product types*	PU deflective/compression behaviour is completely different when compared to TDI/MOCA. As the applications concerned are characterised by strict safety requirements, the difference in deformation behaviour is an issue for Use 2 products. This can cause accidents involving material damage and fatalities. PU rebound is significantly higher with this alternative (the material is more bouncy). This is an issue for Use 2 products, which are supposed to have low bounce-back. The pipes, cables or monopiles should not bounce when placed on the PU parts (the PU parts should absorb the shock). **Conclusion: requirement not met for all products.**
Fatigue *Key requirement for all product types*	PPDI/HQEE outperforms TDI/MOCA. **Conclusion: requirement met for all products.**
Coefficient of Friction *Key requirement for driven heavy duty rollers and tensioner pads*	PU coefficient of friction is insufficient. This is an issue for tensioner pads and driven heavy duty rollers as it can lead to article slippage (e.g. pipe) causing equipment damage or even fatalities. **Conclusion: requirement not met for tensioner pads and driven heavy duty rollers.** **Not a key requirement for spring blocks and non-driven heavy duty rollers.**
Reliability *Key requirement for all product types*	The parts produced with PPDI/HQEE have higher reliability than TDI/MOCA PU products. **Conclusion: requirement met for all products.**
Pot-life[20] and adhesion *Key requirement for all product types except adhesion is not a key requirement for spring blocks*	PPDI/HQEE has lower pot-life than MOCA. The heavy duty rollers covered by this use cannot be casted due to their larger size. In addition, the shorter pot-life is an issue for spring blocks requiring higher hardness's leading to higher risk for defects in PU. For tensioner pads, there is a higher risk of poor adhesion with this alternative. **Conclusion: Heavy duty rollers cannot be casted.** **Tensioner pads and spring blocks can be casted. There is however a higher risk for defects in the PU and higher risk of delamination.**

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[20] Not a product requirement but it is a limiting factor for the casting of products. A short pot life will not give enough time to cast the product.

3.3.3.2.5. Economic feasibility of PPDI/HQEE

PPDI/HQEE PU requires much longer curing times than TDI/MOCA. The longer curing times increases significantly the energy costs of the process (as high as an increase of a factor of 10). LUC Group would need to buy new equipment such as new ovens to implement this alternative at its site. An extension to the current production facilities, including the UK site, would need to be built to accommodate the new equipment. LUC Group estimates it would cost approximately 1.8 M GBP per facility.

Table 25 gives an overview of the change in costs due to the transition to PPDI/HQEE.

Table 25. Qualitative assessment of the change in costs due to the substitution of TDI/MOCA with PPDI/HQEE

Aspect	**PPDI/HQEE vs TDI/MOCA**
Raw material costs	Significantly higher (both PPDI and HQEE are more expensive than TDI and MOCA, respectively)
Energy costs	Significantly higher (10 times higher than with TDI/MOCA)
Personnel costs	No change expected. LUC UK's personnel will not require additional training to use PPDI/HQEE.
Scrap rate	Not applicable

LUC UK has estimated the costs to implement an alternative for Use 2 products to amount to 490-546 k GBP, should a suitable alternative be found. For additional information, please see the substitution costs section and Table 64 in Chapter 4.1.3.1 of the AoA-SEA report of Use 1 of this application.

It would be impossible for LUC UK to absorb such a high material cost. LUC UK cannot increase the price of its products as they have to compete with the non-UK MOCA moulders who can still continue to place TDI/MOCA PU products on the UK market. LUC UK's customers will simply not buy the alternative products at a higher price if they can continue to buy the cheaper TDI/MOCA PU products.

In addition to having higher production costs, the PU products cured with this alternative do not have the high-performance and high reliability needed for this sector. Supply of products with inferior performance and reliability will result in damage to the LUC Group's brand and customers will switch to non-UK MOCA moulders.

3.3.3.2.6. Suitability of PPDI/HQEE for the applicant in general

PPDI/HQEE cannot be considered a suitable alternative to TDI/MOCA in Use 2 products as summarised in Table 26.

Table 26. Limitations of the alternative

<table>
<tr><td colspan="4">– PU CoF is too low for tensioner pads and driven heavy-duty rollers (safety risk)
– PU Deflective behaviour is completely different than TDI/MOCA PUs, which is an issue for all products (safety risk)
– PU Tensile strength is too low (parts could break during use)
– Pot-life is so short that the heavy-duty rollers cannot be casted. There is also a higher risk of PU defects and delamination for spring blocks and tensioner pads
– Longer curing times are required with this alternative
– The higher raw material costs (PPDI and HQEE) and the significantly higher energy costs increases significantly the total production costs</td></tr>
<tr><td>Technical feasibility</td><td>Economic feasibility</td><td>Availability</td><td>Safety considerations</td></tr>
<tr><td>🟥</td><td>🟥</td><td>🟩</td><td>🟩</td></tr>
</table>

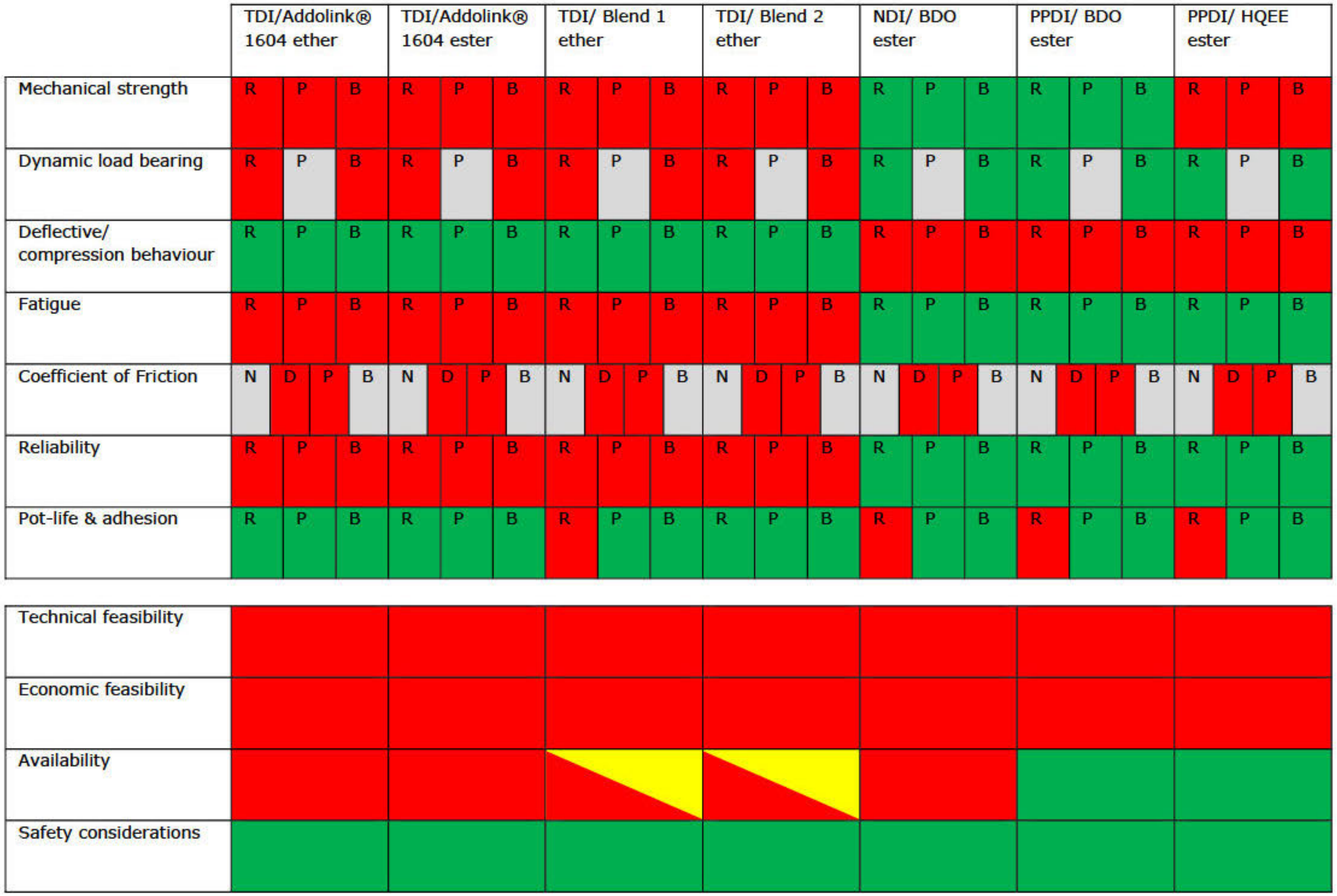
3.4. Conclusion on shortlisted alternatives

Table 27 provides a summary of the assessment of shortlisted alternatives.

Table 27. Alternative assessment summary

(R = heavy duty roller, P = tensioner pad, B = spring block, N = non-driven heavy duty roller, D = driven heavy duty roller)

🟥 Requirement not met
🟨 Fulfilment of the criteria not clear
🟩 Requirement met
⬜ Not a key requirement



	TDI/Addolink® 1604 ether	TDI/Addolink® 1604 ester	TDI/ Blend 1 ether	TDI/ Blend 2 ether	NDI/ BDO ester	PPDI/ BDO ester	PPDI/ HQEE ester
Mechanical strength	R 🟥 P 🟥 B 🟥	R 🟥 P 🟥 B 🟥	R 🟥 P 🟥 B 🟥	R 🟥 P 🟥 B 🟥	R 🟩 P 🟩 B 🟩	R 🟩 P 🟩 B 🟩	R 🟥 P 🟥 B 🟥
Dynamic load bearing	R 🟥 P ⬜ B 🟥	R 🟥 P ⬜ B 🟥	R 🟥 P ⬜ B 🟥	R 🟥 P ⬜ B 🟥	R 🟩 P ⬜ B 🟩	R 🟩 P ⬜ B 🟩	R 🟩 P ⬜ B 🟩
Deflective/ compression behaviour	R 🟩 P 🟩 B 🟩	R 🟩 P 🟩 B 🟩	R 🟩 P 🟩 B 🟩	R 🟩 P 🟩 B 🟩	R 🟥 P 🟥 B 🟥	R 🟥 P 🟥 B 🟥	R 🟥 P 🟥 B 🟥
Fatigue	R 🟥 P 🟥 B 🟥	R 🟥 P 🟥 B 🟥	R 🟥 P 🟥 B 🟥	R 🟥 P 🟥 B 🟥	R 🟩 P 🟩 B 🟩	R 🟩 P 🟩 B 🟩	R 🟩 P 🟩 B 🟩
Coefficient of Friction	N ⬜ D 🟥 P 🟥 B ⬜	N ⬜ D 🟥 P 🟥 B ⬜	N ⬜ D 🟥 P 🟥 B ⬜	N ⬜ D 🟥 P 🟥 B ⬜	N ⬜ D 🟥 P 🟥 B ⬜	N ⬜ D 🟥 P 🟥 B ⬜	N ⬜ D 🟥 P 🟥 B ⬜
Reliability	R 🟥 P 🟥 B 🟥	R 🟥 P 🟥 B 🟥	R 🟥 P 🟥 B 🟥	R 🟥 P 🟥 B 🟥	R 🟩 P 🟩 B 🟩	R 🟩 P 🟩 B 🟩	R 🟩 P 🟩 B 🟩
Pot-life & adhesion	R 🟩 P 🟩 B 🟩	R 🟩 P 🟩 B 🟩	R 🟥 P 🟩 B 🟩	R 🟩 P 🟩 B 🟩	R 🟥 P 🟩 B 🟩	R 🟥 P 🟩 B 🟩	R 🟥 P 🟩 B 🟩
Technical feasibility	🟥	🟥	🟥	🟥	🟥	🟥	🟥
Economic feasibility	🟥	🟥	🟥	🟥	🟥	🟥	🟥
Availability	🟥	🟥	🟥/🟨	🟥/🟨	🟥	🟩	🟩
Safety considerations	🟩	🟩	🟩	🟩	🟩	🟩	🟩

As it can be seen from the table, the alternatives have many limitations, which makes them non-suitable alternatives to TDI/MOCA. The assessment of TDI / Blend 5 ether prepolymer system is not included in the table above as the assessment hasn't been completed yet. Further testing is ongoing as explained in Chapter 3.3.1.2.4.

In terms of technical feasibility, while some alternative cured PUs may perform as well or even better than TDI/MOCA PUs in regards to an individual technical property but do not have the same performance for all key technical requirements for Use 2 products. PU dynamic load bearing capacity is a major issue in the alternative TDI systems. There are also issues with PU tensile strength, reliability and fatigue in these systems. End-users are particularly sensitive to reductions in PU durability as this increase their costs (parts need to be changed or recovered more often resulting in more frequent downtimes). The NDI and PPDI based systems on the other hand give PUs with excellent load bearing capabilities but their deflective behaviour is completely different and their Coefficients of Friction are too low. In addition, their pot-lives are shorter thus, heavy duty rollers cannot be casted.

The lower technical properties of alternative PU products is not only a performance issue but also a safety risk. Offshore installation work requires extreme precision and the requirements on the PU parts are high. They must be highly reliable, durable and behave in a predictable way to prevent disastrous accidents. In addition, the adhesion of the PU to the roller cores or metal plates must be flawless. Delamination can cause significant equipment damage or even fatalities.

Monopiles or pipes have the risk of sliding during transport if the tensioner pads they are resting on have too low coefficient of friction. All three product types have the risk of powdering and cracking if their tensile strengths are insufficient. These defects may cause the pipes, monopiles or cables to slip causing accidents involving equipment damage, causing harm to workers or lead to fatalities. In worst cases, the entire vessel may sink.

Availability is an issue for many of the alternatives, especially in the volumes needed by LUC Group to replace MOCA, keeping in mind that substitution related decisions are taken on a Group level. Only the PPDI-based systems are readily available in sufficient quantities. The full substitution of MOCA would however, require a tonnage update of LUC Group's EU REACH registration dossier to 10-100 t/y (LUC Group would act as the supplier for LUC UK). As the lead registrant, LUC Group would need to make a significant investment to upgrade their registration dossier.

In terms of economic feasibility, the implementation of alternatives would require significant investments from LUC UK (an estimated 490-546 k GBP in total). The estimate covers the purchase of new equipment and machinery (casting machines, feeders, curing ovens etc.), labour costs (R&D personnel, production workers etc.), administrative and regulatory costs. For additional information, please refer to the substitution costs section in Chapter 4.1.3.1 of the AoA-SEA report of Use 1 of this application

The production costs of all alternatives are higher than the ones for MOCA. All alternatives have higher raw material costs, as high as 13 times the price of MOCA. In addition, many of the alternatives have higher energy costs and scrap rates. Economically, this is a major issue for LUC UK due to i) distortion of the market by TDI/MOCA-PU products from outside the UK and ii) the lack of motivation of the end-users.

i. As the finished PU products do not contain any MOCA, they are not affected by the ban. Thus, non-UK moulders can continue freely to place their TDI/MOCA-PU products on the UK market. LUC UK has to compete with these products both in terms of price and performance. This puts LUC UK in the vulnerable position where their clients (the end-users) may leave them for a non-UK moulder at any time. Thus, any non-MOCA based products LUC UK manufactures must perform at least as well as their TDI/MOCA-counterparts. This means that it is essentially impossible for LUC UK to reflect the substitution costs and the higher production costs in the price of the alternative PU products.

ii. LUC UK's customers are accustomed to use TDI/MOCA-PU products and they have no motivations of changing. As demonstrated in the previous sections, the alternative PU products are more expensive to produce while their performances are lower. LUC UK's customers have little motivation to pay more for a relatively non-proven PU product that potentially performs worse during end-use (over the lifetime of the article). As LUC UK's customers have no driver to transfer to non-MOCA based products, there is a very real risk that they prefer to stick with what they know and stay with MOCA/TDI PU products. If LUC UK's customers were in the same situation where they would also need to find alternatives, the situation would be easier in that the goal would be a common one. However, the current situation is that end-users are only concerned about price and performance.

In conclusion, in order to remain competitive, LUC UK would either need to provide an alternative PU product performing as well as their TDI/MOCA counterparts for the same price or a better performing product for a higher cost. The alternatives discussed fulfil neither.

4. SOCIO-ECONOMIC ANALYSIS

4.1. Continued use scenario

4.1.1. Summary of substitution activities

For the summary of substitution activities, please see Chapter 4.1.1 in the AoA-SEA report of Use 1 of this application

4.1.2. Conclusion on suitability of available alternatives in general

There are currently **no suitable alternatives to MOCA** for the manufacture of the high-performance PU products covered by this use. Therefore, LUC Group will need to continue their R&D efforts to find a suitable replacement. As all the potential alternatives currently available on the market have already been tested by LUC Group, it is uncertain when a new potential alternative to MOCA for the products covered by this application can be found. LUC Group has defined an R&D plan in case a suitable alternative is found.

4.1.3. R&D plan

For the description of the R&D plan, please see Chapter 4.1.3 in the AoA-SEA report of Use 1 of this application.

The R&D plan is valid for both Use 1 and Use 2.

4.1.3.1. Factors affecting substitution

For the description of the factors affecting substitution, please see Chapter 4.1.3.1 in the AoA-SEA report of Use 1 of this application.

4.1.3.2. List of actions and timetable with milestones

For the description of the list of actions and timetable with milestones, please see Chapter 4.1.3.2 in the AoA-SEA report of Use 1 of this application.

4.1.3.3. Monitoring of the implementation of the R&D plan

For the description of the monitoring of the implementation of the R&D plan, please see Chapter 4.1.3.3 in the AoA-SEA report of Use 1 of this application.

4.1.3.4. Conclusions

For the description of the conclusions, please see Chapter 4.1.3.4 in the AoA-SEA report of Use 1 of this application.

4.2. Risks associated with continued use

4.2.1. Impacts on humans

For the impacts on humans, please see Chapter 4.2.1 in the AoA-SEA report of Use 1 of this application.

4.2.1.1. Number of people exposed

For the information on the number of people exposed, please see Chapter 4.2.1.1. in the AoA-SEA report of Use 1 of this application.

4.2.2. Impacts on environmental compartments

Environmental impacts are not relevant for the proposed identification of the substance as an SVHC in accordance with article 57 (a & b).

4.2.3. Compilation of human health and environmental impacts

For the information on human health and environmental impacts concerning overall uses of MOCA by LUC UK, please see Chapter 4.2.3. in the AoA-SEA report of Use 1 of this application.

The sum of fatal and non-fatal cancer risk value of LUC UK's use (worker + local + regional) in 2021 price level is approx. 0.00013 M GBP based on the lower value and 0.00020 M GBP based on the higher value with the maximum forecasted tonnage. The average per year for the higher bound is 0.000017 M GBP.

Monetised cancer risk related to Use 2:

32 % * 0.000017 M GBP per year = 0.000005 M GBP

This figure is taken forward to the comparison of benefits and risks.

4.3. Non-use scenario

For the description of the non-use scenario, please see Chapter 4.3. in the AoA-SEA report of Use 1 of this application.

4.3.1. Summary of consequences of non-use

For the summary of consequences of non-use, please see Chapter 4.3.1. in the AoA-SEA report of Use 1 of this application.

4.3.2. Identification of plausible non-use scenarios

For the identification of plausible non-use scenarios, please see Chapter 4.3.2. in the AoA-SEA report of Use 1 of this application.

4.3.3. Conclusion on the most likely non-use scenario

For the conclusion on the most likely non-use scenario, please see Chapter 4.3.3. in the AoA-SEA report of Use 1 of this application.

4.4. Societal costs associated with non-use

4.4.1. Economic impacts on LUC UK

For the derivation of overall economic impacts on LUC UK, please see Chapter 4.4.1. in the AoA-SEA report of Use 1 of this application.

Summary of monetised impacts on LUC UK

The total negative economic impact on LUC UK is summarised in Table 28.

Table 28. Economic impact on LUC UK

Cost item	Over period	Annualised / Average
Producer surplus lost in the UK	0.7 M GBP over 4 years	0.2 M GBP per annum
Decommissioning cost	0.44 M GBP over 12 years	0.04 M GBP per annum

As mentioned, 32 % of the revenue is allocated for Use 2. As a consequence, 32 % of the impacts is allocated for Use 2. The total negative economic impact on LUC UK for Use 2 is summarised in Table 28.

Table 29. Economic impact on LUC UK for Use 2

Cost item	Over period	Annualised / Average
Producer surplus lost in the UK	0.21 M GBP over 4 years	0.05 M GBP per annum
Decommissioning cost	0.14 M GBP over 12 years	0.01 M GBP per annum

4.4.2. Economic impacts on the supply chain

For the economic impacts on the supply chain, please see Chapter 4.4.2. in the AoA-SEA report of Use 1 of this application.

4.4.3. Economic impacts on competitors

For the economic impacts on competitors, please see Chapter 4.4.3. in the AoA-SEA report of Use 1 of this application.

4.4.4. Wider socio-economic impacts

For the wider economic impacts and the derivation of quantified social impacts and corporate tax losses, please see Chapter 4.4.4. in the AoA-SEA report of Use 1 of this application.

As mentioned, 32 % of the revenue is allocated for Use 2. As a consequence, 32 % of the social impacts is allocated for Use 2. The societal impacts for LUC UK for Use 2 are summarised in Table 30.

Table 30. Monetised societal cost

LUC UK	Value
Use 2: Total societal cost	0.21 M GBP
Use 2: Annualised societal cost	0.02 M GBP

The negative social impacts of a refused authorisation for Use 2 are approx. 0.21 M GBP for the society in the UK. Annualised to the review period applied for (12 years), this equals to approx. 0.02 M GBP.

32 % of the corporate tax loss is 0.04 M GBP over four years and 0.01 M GBP annually.

4.4.5. Compilation of socio-economic impacts

Societal costs associated with the non-use for Use 2 are outlined in Table 31.

Table 31. Societal costs associated with non-use for Use 2

Description of major impacts	**Monetised impacts**	
1. Monetised impacts	**Over period**	**Annualised / Average**
Producer surplus loss due to ceasing the use applied for in the UK	0.21 M GBP over 4 years	0.05 M GBP per year
Decommissioning cost	0.14 M GBP over 12 years	0.01 M GBP per year
Social cost of unemployment	0.21 M GBP over 12 years	0.02 M GBP per year
Corporate tax loss	0.04 M GBP over 4 years	0.01 M GBP per year
Sum of monetised impacts	**0.6 M GBP**	**0.09 M GBP per year**

4.5. Combined impact assessment

To make the impacts comparable, the following comparison uses annual figures instead of figures over period since the periods are different (e.g. 4 years for producer surplus and 12 years for decommissioning cost and human health impacts). Societal costs of non-use and risk of continued use are outlined in Table 32.

Table 32. Societal costs of non-use and risks of continued use

Societal costs of non-use		**Risks of continued use**	
Monetised impacts	0.09 M GBP per year	Monetised excess risks to directly exposed workers	< 0.000001 M GBP (1 GBP) per year
Additional quantitatively assessed impacts	n.a.	Monetised excess risks to the general population	0.000005 M GBP (5 GBP) per year
Qualitatively assessed impacts	n.a.	Qualitatively assessed risks	n.a.
Summary of societal costs of non-use	0.09 M GBP per year	**Summary of risks of continued use**	0.000005 M GBP (5 GBP) per year

In conclusion, the societal cost of non-use outweighs the risk on continued use significantly (0.09 M GBP versus ca. 0.000005 M GBP (5 GBP). The benefit-cost ratio compares how many times the benefits outweigh the costs, and the result is 18,000 times.

4.6. Sensitivity analysis

For the sensitivity analysis, please see Chapter 4.6. in the AoA-SEA report of Use 1 of this application.

4.7. Information to support for the review period

Despite the extensive R&D work conducted by LUC Group, there is currently no suitable alternative to replace MOCA as a curing agent/chain extender in the production of the high-performance PU products covered by this application. There are several issues with the alternatives currently on the market, which includes poor mechanical and dynamic properties of the alternative PU, low CoF, pot-life issues, high production costs and availability issues.

LUC UK is requesting for a review period of 12 years. As currently there are no suitable alternatives to replace MOCA in the manufacture of their high-performance PU products, LUC Group will need to look for and test new alternatives that could provide products with the same technical properties as MOCA. This is a lengthy process and there are uncertainties when a new potential alternative will be available. In addition, the substitution work itself takes years to complete due to the rigorous testing and customer trials required. Please see the substitution plan report submitted with this application for additional information.

In Table 33, the criteria set by the Committees for Socio-economic Analysis (SEAC) and Risk Assessment (RAC) for requesting a long review period are presented along with how LUC UK’s situation reflects these criteria. As it can be seen, LUC UK’s situation fulfils the criteria for a long review period of 12 years. In particular, LUC UK has demonstrated that there is no suitable alternative for MOCA in the manufacture of the high-performance PU products concerned by this use. LUC Group has conducted extensive research and testing on potential alternatives since 2009. These R&D efforts have already cost LUC Group more than 0.5 M GBP.

Table 33. The criteria for a long review period[21]

Criterion	**Situation for the applicant**
The costs of using the alternatives are very high and very unlikely to change in the next decade as technical progress (as demonstrated in the application) is unlikely to bring any change. For example, this could be the case where a substance is used in very low tonnages for an essential use and the costs for developing an alternative are not justified by the commercial value.	TDI/MOCA is known to be an inexpensive and reliable system for manufacturing high-performance PU's. In comparison, alternative curing agents/PU systems are more expensive, both in terms of material, process and energy costs. Alternative systems are also typically less reliable in production, which increase the number of rejected parts (i.e. scrap rate). As LUC UK cannot reflect the increased production costs in their products due to competing MOCA PU products produced outside of the UK, the products manufactured with an alternative system are not economically viable for LUC UK.
The applicant can demonstrate that research and development efforts already made, or just started, did not lead to the development of an alternative that could be available within the normal review period.	LUC Group has researched and tested potential alternatives to MOCA for more than a decade for a cost of over 0.5 M GBP. During that time, LUC Group has been able to successfully replace MOCA in the manufacture of some of their products (25 % of their MOCA PU product portfolio) because the technical requirements in these PU products were lower. For the high-performance products covered by this use, the technical requirements are higher as they are used in highly demanding applications. There is currently no alternative to MOCA for the manufacturing of these products.
The possible alternatives would require specific legislative measures under the relevant legislative area in order to ensure safety of use (including acquiring the necessary certificates for using the alternative).	Every alternative product need to be tested in end-user facilities. During trials, the part is tested to assess whether it fulfils customer requirements. As the durability and reliability of the product needs to be assessed as well, the trials take several years.
The remaining risks are low and the socio-economic benefits are high, and there is clear evidence that this situation is not likely to change in the next decade.	There are no emissions to water and measures to ensure worker health and safety are in place in the facilities and LUC UK is continuously improving its risk management measures. Benefits outweigh the costs significantly. For both uses, the costs for LUC UK are ca. 18,000 times higher than the human health costs for society.

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[21] https://echa.europa.eu/documents/10162/13580/seac_rac_review_period_authorisation_en.pdf

5. CONCLUSION

The aim of this combined Analysis of Alternatives (AoA) and Socio-economic Analysis (SEA) report was to: 1) demonstrate that no suitable alternative substances or technologies are implementable by LUC UK by the expiry of the extended sunset date MOCA under UK REACH passes on 30th of June 2022 and 2) to demonstrate that the socio-economic benefits of the continued use of MOCA outweigh the risks to human health and environment.

Since June 2009, LUC Group has tested dozens of non-MOCA based chain extenders and polyurethane systems including like-for-like diamine alternatives, chain extender blends and non-TDI PU systems. As it can be seen from the AoA, all the alternatives tested have many limitations making them unsuitable to replace TDI/MOCA in LUC' UKs production of high-performance PU products in this use.

In terms of technical feasibility, the mechanical and dynamic properties of some alternatives is too low especially in terms of load bearing capacity and mechanical strength. For some PU systems, PU CoF is also an issue. In addition, many alternative PU systems have issues with PU fatigue, reliability and system pot-life. End-users are particularly sensitive to reductions in reliability and fatigue as this increase their costs (parts need to be changed or recovered more often resulting in more frequent downtimes).

The lower technical properties of alternative PU products is not only a performance issue but also a safety risk. Only high-performance PU is suitable to be used in Use 2 products as failures could cause tremendous damage to the ship and lead to injury or loss of life.

Some alternatives are also currently unavailable or have limited availability, which further complicates the substitution of MOCA.

In terms of sustainability, the alternative PU materials had higher environmental loads compared to MOCA PU. The main reasons behind the lower sustainability of alternative PU's include lower fatigue properties, longer curing times, higher energy needs and/or higher scrap rate. This results into higher amounts of waste generated and higher energy consumption to produce the same amount of PU parts.

In addition to having lower technical performance, alternatives are also more expensive. All alternatives have higher raw material costs, as high as 13 times the price of MOCA and many also have higher energy costs and scrap rates. This is a major issue for LUC UK due to the distortion of the market by TDI/MOCA-PU products from outside of the UK and the lack of motivation of the end-users (LUC UK's customers).

LUC UK's customers are accustomed to use TDI/MOCA PU products and they have no motivation to pay more for a relatively non-proven PU product that potentially performs worse during end-use. As LUC UK's customers have no driver to transfer to non-TDI/MOCA based PU products, there is a very real risk that they prefer to stick with what they know and stay with MOCA-TDI PU products. If LUC UK's customers were in the same situation where they would also need to find alternatives, the situation would be easier in that the goal would be a common one. However, the current situation is that end-users are only concerned about price and performance.

In conclusion, LUC UK has to compete with competitor products coming from outside the UK both in terms of price and performance. Thus, in order to remain competitive, LUC UK would either need to provide an alternative PU product performing as well as their MOCA counterparts for the same price or a better performing product for a higher cost. The alternatives currently available on the market fulfil neither.

The most likely non-use scenario for LUC UK would be business closure and the TDI/MOCA high-performance PU production would be relocated to LUC Group's facilities in the EU. The UK society would benefit from the business closure only in terms of reduced cancer risk for the workers and general population. The human health value, the risk of continued use of MOCA for society for Use 2, is 0.000005 M GBP (5 GBP) per year. The benefit of continued use of MOCA for society are the avoided cost of the non-use scenario (the producer's surplus cost, decommissioning cost, corporate tax loss and societal cost from job losses). For Use 2, the benefit is 0.09 M GBP per year. The benefit-risk ratio of the continued use of MOCA for Use 2 is ca. 18,000 (0.09 M GBP / 0.000005 M GBP). The benefits outweigh the risks significantly.

As outlined in Chapter 1, MOCA use at the LUC UK site fulfils the three conditions for "intermediate use" as given in the European Court of Justice (C -650/15/P[5]) decision and further clarified in the revised ECHA guidance of March 2022[6]. Intermediate use is exempt from the authorisation requirement. LUC UK is submitting this application as a contingency measure as it is not yet clear how to document this decision for the relevant authorities in the UK.

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